Title: RECEIVER FOR AN AUTOMATED METER READING SYSTEM

Abstract: An automatic meter reading (AMR) system is shown in Figure 1. The system has a plurality of endpoints (204) for bi-direction communications, a plurality of collection transceivers with a range that defines a principle coverage area (209a-209c) for receiving information from the endpoints, and a utility database (202) for storing some of the received information. The AMR system coverage can be improved by providing auxiliary transceivers (220a-220e) in a fixed location such that the coverage of the auxiliary covers areas not within the principle coverage areas of the collection transceivers. The auxiliary transceivers operate in a low power mode and communicate information received from endpoints to the collection transceivers.
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RECEIVER FOR AN AUTOMATED METER READING SYSTEM

RELATED APPLICATIONS
The present application claims priority to U.S. Patent Application No. 11/105,663, entitled "SYSTEM AND METHOD FOR IMPROVING OR EXPANDING COVERAGE IN A METER READING SYSTEM," and filed April 14, 2005.


FIELD OF THE INVENTION
The present invention relates to a method and system for collecting data from remote utility meters and, more particularly, to a system and method for improving coverage of an automated meter reading system without substantially increasing the cost of the overall system.

BACKGROUND OF THE INVENTION
Wireless automatic meter reading (AMR) systems are well known. Typically, each utility meter is provided with a battery-powered encoder that collects meter readings and periodically transmits those readings over a wireless network to a central station. The power limitations imposed by the need for the encoder to be battery powered and by regulations governing radio transmissions effectively prevent direct radio transmissions to the central station. Instead, wireless AMR systems typically utilize a layered network of overlapping intermediate receiving stations that receive transmissions from a group of meter encoders and forward those messages on to the next higher layer in the network as described, for example, in U.S. Patent No. 5,056,107. These types of layered wireless transmission networks allow for the use of lower power, unlicensed wireless transmitters in the thousands of endpoint encoder transmitters that must be deployed as part of a utility AMR system for a large metropolitan area.

One challenge faced by designers of wireless meter reading systems involves providing adequate coverage with transceivers located in the field that are receiving data from metering units that will be transmitted back to the utility. Current meter reading systems use high sensitivity receivers placed on utility poles to read as many meter
modules as possible. These receivers are expensive and therefore must cover a large area. Signal multipathing and attenuation due to buildings, fences, and other structures cause holes in the coverage area. In order to fill these holes, additional receivers have to be placed in the coverage area, increasing the cost of the system. Additional transceivers may also be needed to provide reliable communications with meter modules located near the periphery of the coverage area and in only marginal communications range of a presently installed system transceiver. As housing development expands the areas needing communications coverage, utilities can experience the problem of overcapacity – that is, investing in expensive transceivers having high-sensitivity, high-capacity receivers for servicing new developments having far fewer meter modules than such receivers can accommodate. A goal in designing these systems is to achieve a balance of coverage and hardware invested in the meter reading system.

Installation of additional transceivers presents further challenges for utility providers. Typically, system transceivers utilizing high-sensitivity, high-capacity receivers include circuitry that operates continuously, or with high enough duty cycles, and consuming enough power, to require externally supplied electrical energy. In practice, locations determined to be desirable for system transceiver placement often do not have easily accessible line power. Tapping power distribution circuits and running wires dedicated to powering additional system transceivers presents substantial burden and cost for utilities.

**SUMMARY OF THE INVENTION**

According to one aspect of the invention, an automatic meter reading (AMR) communications system has a plurality of endpoints adapted for two-way communications, a plurality of collection transceivers having a communications range that defines a principal coverage area and adapted to receive information from endpoints located in the principal coverage area, and a utility database adapted for storing at least some of the received information. AMR system coverage can be improved by at least providing an auxiliary transceiver in a fixed location, such that the auxiliary transceiver has a communications range that defines an auxiliary coverage area. The auxiliary transceiver can be automatically operated in a low-power standby mode during a first time duration, and automatically operated in an active mode during a second time duration that is shorter than the first time duration. Operating the auxiliary transceiver during the second time duration includes exiting the standby mode to enter an active operating mode,
communicating with an endpoint on a prompt-response basis, receiving information transmitted from the endpoint located in the auxiliary coverage area in response to the prompt-response communications, and transmitting at least a subset of the received endpoint information to at least one of the plurality of collection transceivers.

**BRIEF DESCRIPTION OF THE DRAWINGS**

The invention may be more completely understood in consideration of the following detailed description of various embodiments of the invention in connection with the accompanying drawings, in which:

FIG. 1 is a diagram illustrating an example AMR system in which utility meter endpoints are capable of two-way communication.

FIG. 2 is a diagram illustrating examples of portable and mobile meter reading devices in the context of the AMR system of FIG. 1.

FIG. 3 is a flow diagram illustrating an example method of operating an auxiliary transceiver according to one embodiment of the present invention.

FIG. 4 is a diagram illustrating examples of applications for various embodiments of auxiliary transceivers in the context of the example AMR system of FIG. 1.

While the invention is amenable to various modifications and alternative forms, specifics thereof have been shown by way of example in the drawings and will be described in detail. It should be understood, however, that the intention is not to limit the invention to the particular embodiments described. On the contrary, the intention is to cover all modifications, equivalents, and alternatives falling within the spirit and scope of the invention as defined by the appended claims.

**DETAILED DESCRIPTION OF THE INVENTION**

One aspect of the invention is directed to communications coverage improvement or extension in AMR systems in which utility meter endpoints have the capability of bi-directional communication. FIG. 1 illustrates one example embodiment of an AMR system, which is generally indicted at 200. AMR system 200 includes a central utility database 202 that ultimately receives utility consumption information from the plurality of individual utility meter endpoints 204a-204r (generally referred to herein as utility meter endpoints 204). Each utility meter endpoint 204 includes a radio transceiver (or ERT-encoder reader transmitter) that can be communicatively coupled to the utility database 202 via an AMR communications infrastructure that includes a central transceiver (or
collector) 206. Central transceiver 206 receives transmitted consumption information corresponding to each utility meter, converts the information into a form usable by database 202, and forwards the information to database 202.

Central transceiver 206 is not illustrated in Fig. 1 as communicating directly with meter endpoints 204. However, in a related embodiment, central transceiver 206 is adapted to communicate with at least some of meter endpoints 204. In example AMR system 200, most of utility meter endpoints 204 communicate consumption information to central transceiver 206 via intermediate transceivers 208a, 208b, and 208c (generally referred to herein as intermediate transceivers 208). In one embodiment, intermediate transceivers 208 receive consumption information in the form of RF telemetry data from utility meter endpoints 204 located within their RF communications range, and re-transmit the information to central transceiver 206 over a corresponding communications channel. In one embodiment, the communications channel is a wireless RF link such that intermediate transceivers 208 operate in the nature of RF repeaters. Physically, such an embodiment can be implemented by intermediate transceivers 208 each including a highly directional antenna pointed at the central transceiver and driven by a suitable transmitter having sufficient power to ensure a desired level of transmission reliability. In another embodiment, the communications channel includes a wired network. Data communication from intermediate transceivers 208 can be bi-directional, as represented by communication 210a between intermediate transceiver 208a and central transceiver 206; or unidirectional, as represented by communication 210b from intermediate transceiver 208b to the central transceiver 206. Also, communication can be relayed from one intermediate transceiver 208c to another intermediate transceiver 208b, and ultimately to central transceiver 206, as represented by communication 210c between intermediate transceivers 208c and 208b, and communication 210b from intermediate transceiver 208b to central transceiver 206.

Each intermediate transceiver 208 is installed in a fixed location and has a limited communications range for communicating with utility meter endpoints. Therefore, each intermediate transceiver is capable of communicating only with utility meter endpoints located in its coverage area. As illustrated in FIG. 1, intermediate transceivers 208a, 208b, and 208c have coverage areas 209a, 209b, and 209c, respectively. Together, intermediate transceivers 208a, 208b, and 208c service a principal coverage area generally indicated at 209. Intermediate transceivers 208 have high-capacity, high sensitivity RF receivers. In order to service large numbers of utility meter endpoints, the receivers are configured to operate during a majority of the time. Because such receivers consume a relatively large
amount of power, intermediate transceivers 208 are typically installed with externally supplied power, such as from the AC mains. In one embodiment, each intermediate transceiver 208 is capable of communicating with, or servicing, hundreds or even thousands of utility meter endpoints in its corresponding coverage area. Examples of communications between utility meter endpoints 204 and intermediate transceivers 208 are illustrated in FIG. 1 and generally indicated at 205. For instance, utility meter endpoint 204a communicates with intermediate transceiver via communications link or signal 205a.

Coverage areas 209a, 209b, and 209c have overlapping portions, such as the coverage area portions that include utility meter endpoints 204b, 204c, and 204i. Each of these utility meter endpoints is within communications range of more than one intermediate transceiver 208, and indeed communicates with more than one intermediate transceiver 208. For example, utility meter endpoint 204b communicates with intermediate transceiver 208a via communications link 205b1, and with intermediate transceiver 208b via communications link 205b2. Likewise, utility meter endpoint 204c communicates with intermediate transceiver 208a via communications link 205c1, and with intermediate transceiver 208b via communications link 205c2; and utility meter endpoint 204i communicates with intermediate transceiver 208a via communications link 205i1, and with intermediate transceiver 208c via communications link 205i2. In one embodiment, each of the intermediate transceivers 208 is unaware of message duplication within the system. Thus, when more than one intermediate transceiver 208 receive the same message containing utility meter information, each intermediate transceiver processes the message in its usual manner, and forwards the utility meter information to central transceiver 206 and database 202, which is ultimately responsible for sorting out redundant units of information. This characteristic of example AMR system 200 permits the use of additional, and potentially duplicative, intermediate-level transceivers.

When communicating with an intermediate transceiver 208, each utility meter endpoint 204 can use unidirectional communication, such as the communications link 205l from utility meter endpoint 204l to intermediate transceiver 208c, or bidirectional, such as communication link 205m between utility meter endpoint 204m and intermediate transceiver 208c. Because the communications modules in the utility meter endpoints 204 are typically battery powered, it is desirable for the AMR system to minimize the number of transmissions required for the utility meter endpoints 204 to transmit their consumption information. To this end, in one embodiment, utility meter endpoints 204 utilize an
infrequent bubble-up mode of occasional data transmission where a utility meter automatically wakes up according to a random, quasi-random, or predetermined time interval and begins transmitting its telemetry-gathered data.

Each communication associated with a bubble-up event can itself be either unidirectional or bi-directional. In the case of a bi-directional communication, in one embodiment, the flow of information is usually from the utility meter endpoint 204 to the corresponding intermediate transceiver 208, such that the data bits originating at the intermediate transceiver 208 and received by utility meter endpoint 204 are used for implementing the transport layer protocol (for example, frame preamble bits, parity bits, acknowledgement frames, etc.).

In an alternative embodiment, bidirectional communications are utilized to transmit information from the AMR system infrastructure to one or more utility meter endpoints 204. In another embodiment, as an alternative to a bubble-up scheme, bi-directional communications are used to prompt one or more utility meter endpoints to initiate data transfer of consumption information (or metered data). In another embodiment, utility meter endpoints 204 are capable of operating in one or more differing modes, such as in a bubble-up mode at certain times, and in a prompt-response (or wake-up) mode at other times.

In one embodiment, one of the utility meter endpoints 204 that is receptive to inbound communications includes low-power intermittently-operating receiver circuitry for detecting the presence of a signal having predefined properties characteristic of an inbound communication addressed to a specific meter endpoint or to a group of meters to which that specific meter endpoint (or targeted endpoint) belongs. When such a signal is detected, the receiver circuitry causes the utility meter endpoint to power the receiver circuitry for a sufficient time to receive and decode the inbound communication. In one example embodiment, a utility meter endpoint 204 operates intermittently in a signal detect mode for several milliseconds every 10-20 seconds. Between detection operations, the circuitry is in an extremely low-power-consuming standby mode. In one embodiment, the low-cost receiver circuitry described above with respect to FIG. 4 is utilized in each utility meter endpoint 204.

In example AMR system 200, utility meter endpoints 204 are capable of bubble-up, as well as prompt-response or wake-up modes of communication. In one embodiment, utility meter endpoints 204 typically operate in a bubble-up mode; however, the diversity of available operating modes permits the AMR system to be highly adaptable to any
changing operating requirements or conditions. For example, utility meter endpoint 204g occasionally transmits its consumption information to intermediate transceiver 208b via communication link 205g, which occurs at random variations about a predetermined interval. The utility provider may wish to communicate with utility meter endpoint 204g at an additional instance.

FIG. 2 illustrates examples of communications devices that are not a part of the infrastructure of AMR system 200. A portable communicator 212 provides a way for a human meter reader or technician to communicate in close proximity with utility meter endpoint 204g at a desired time. Portable communicator 212 initiates RF communication 213a by transmitting a message, in response to which utility meter endpoint 204g wakes up and transmits a reply message. In this way, portable communicator 212 can be used, for example, to read consumption or other information from utility meter endpoint 204g, or to reconfigure utility meter endpoint 204g. Portable communicator 212 can relay information received from utility meter endpoint 204g to central transceiver 206 and utility database 202 via communication link or signal 215 to intermediate transceiver 208b, which in turn is relayed via communication 210b from intermediate transceiver 208b to central transceiver 206. In this example embodiment, portable communicator 212 is a human-operated, battery-powered device and is typically not adapted for long-term automatic operation (i.e., without human intervention) such as equipment typically used in fixed AMR networks.

Utility personnel may also operate a mobile communicator 214, also illustrated in FIG. 2, which can initiate RF communications with a utility meter endpoint, such as utility meter endpoint 204h, and later transfer information obtained from the meter endpoint to utility database 202. In another embodiment, mobile communicator 214 is mounted on a street vehicle and coupled to a portable data collector. Data received by mobile communicator 214 and collected by the data collector can later be transferred to utility database 202 via a data transfer transmission 217. Because portable communicator 212 and mobile communicator 214 are designed to operate at a relatively close range to the utility meter endpoints with which communicators 212, 214 are communicating their receiver circuitry can be of a type that has low sensitivity and a low cost.

Referring again to FIG. 1, the principal coverage area 209 of example AMR system 200 has a finite outer limit. Coverage area 209 also has gaps 216 and 218 in coverage. Gap 216 is a void within coverage area 209b, and is therefore an area outside of the principal coverage area 209. Gap 218 is outside the boundary of coverage areas 209a
and 209b at a location where the boundaries have failed to overlap. Utility meters 204e, 204f, 204j, 204k, 204n, 204p, 204r, and 204q are all located outside of principal coverage area 209, and cannot be serviced by the installed principal infrastructure that includes intermediate transceivers 208. Although portable communicator 212 and mobile communicator 214 (FIG. 2) could be deployed to service these utility meters, doing so involves committing human resources to the field to operate the mobile devices 212 and 214, which is a costly and time-consuming endeavor.

According to one aspect of the invention, one or more low-cost auxiliary transceivers, such as auxiliary transceivers 220a, 220b, 220c, 220d, and 220e illustrated in FIG. 4 (generally referred to herein as auxiliary transceivers 220) can be installed to supplement the communications infrastructure of AMR system 200 to provide communications service for utility meter endpoints located outside all of coverage area 209 boundaries, or located in a coverage gap. An auxiliary transceiver 220 can be used as a communications repeater for extending or improving communications coverage in an AMR system. Each auxiliary transceiver 220 includes at least one radio transceiver and at least one antenna for communicating with utility meter endpoints 204, and with the AMR system communications infrastructure. Each auxiliary transceiver 220 also includes a CPU that governs operation of the auxiliary transceiver. In one embodiment, the transmission to the AMR communications infrastructure is directed to a nearby one or more intermediate transceivers 208. In an example of the AMR system operation, each auxiliary transceiver 220 communicates with utility meter endpoints 204 that are located within its auxiliary coverage area, wirelessly receives their consumption and other information destined ultimately to utility database 202, and wirelessly transmits the information to the AMR communications infrastructure via one or more intermediate transceivers 208.

Auxiliary transceiver 220, in certain embodiments, has features and operability that enable auxiliary transceiver 220 to interface with utility meter endpoints having two-way communications capabilities, and utilize this ability to operate with sufficiently low power consumption to enable operation without externally-supplied power. In one embodiment, auxiliary transceiver 220 is powered by at least one battery that is on-board, or integrally housed with the auxiliary transceiver. The use of on-board power greatly facilitates locating and installing the auxiliary transceiver in a preferred field location. In one embodiment, a battery-powered auxiliary transceiver 220 can operate for up to ten years without maintenance or human intervention. An auxiliary transceiver 220 according to
this embodiment can be installed without having to connect to AC mains or other externally supplied power. Avoiding connection to AC power provides substantial savings in installation costs, makes possible installations in locations where AC power is unavailable, saves the cost of electrical hardware needed to make the electrical connections, and saves the cost of electronic hardware needed to condition and convert the mains power into a form suitable for powering the various circuitry. In one embodiment, on-board battery power is supplemented by solar power cells.

FIG. 3 illustrates an example operating sequence 300 of one example embodiment of an auxiliary transceiver. At 302, the auxiliary transceiver is preconfigured and installed in a suitable location to service utility meter endpoints 204 that are outside of coverage area 209. In one embodiment, the pre-configuration includes programming one or more assigned RF channels, the time period between automatic activations, and the duration of each automatic activation. At 304, the auxiliary transceiver self-activates and transmits, or broadcasts, a prompting signal on its assigned RF channel. In this example embodiment, the prompt includes a wakeup sequence of bits to which utility meter endpoints respond by entering an active mode of communication. The prompt can also include a command and control frame according to the system communication protocol. In a related embodiment, the prompt is a fixed sequence that does not vary due to any potentially changing external factors or circumstances.

In one example system operation, all utility meter endpoints that receive the prompting signal, respond to the prompt. In another example system operation, the prompting signal includes an indication that the prompting signal originates from an auxiliary transceiver, and only those utility meter endpoint that are configured to respond to prompts from auxiliary transceivers, respond to the prompt. In another example system operation, utility meter endpoints are each assigned to at least one communications group; and the prompting signal includes a communications group ID. Only those utility meter endpoints that have a communications group membership corresponding to the group ID in the prompt, respond.

At 306, the auxiliary transceiver activates its receiver circuitry by exiting a low-power standby mode, and listens for a pre-configured time duration for any transmissions responsive to the broadcast prompt. At 308, if any responsive messages are transmitted, the auxiliary transceiver receives them, and stores them in memory at 310.

At 312, the auxiliary transceiver pauses. In one embodiment, the pause is for a random time duration not exceeding 10 minutes. In one embodiment, during the pause,
the auxiliary transceiver energizes its transmitter circuitry in preparation for sending the received information to the AMR system infrastructure. At 314, the auxiliary transceiver retrieves the first stored message from memory, transmits the message to an intermediate transceiver of the AMR system, and deletes the message from its memory. In this embodiment, the transmitted message includes additional forward error correction or other suitable transport layer improvement. In a related embodiment, the transmission by the auxiliary transceiver is in a one-way communications mode, in which the auxiliary transceiver does not require any communication from any intermediate transceiver. In an alternative embodiment, the communications between the auxiliary transceiver and the intermediate transceiver are in a 1.5-way communication mode, in which the auxiliary transceiver requires some degree of responsiveness from the auxiliary transceiver, such as frame receipt acknowledgements (ACKs). In another alternative embodiment, communications between the auxiliary transceiver and the intermediate transceiver are in a two-way communication mode, in which the auxiliary transceiver transmits endpoint information in response to prompting signals from the intermediate transceiver that are directed to utility meter endpoints and seek endpoint data.

If there are more messages in memory (316), the auxiliary transceiver retrieves those messages in sequence, and transmits each message (318) in the same manner as described above at 314. After all messages have been sent, the auxiliary transceiver enters a low-power standby mode and counts down until the next activation cycle (320, 322).

The low power standby mode permits auxiliary transceiver 220 to significantly conserve power. In this example embodiment, auxiliary transceiver 220 is in a low power standby mode for over 50% of the time. For example, auxiliary transceiver 220 can operate in a low power mode more than 99% of the time, and operate in active receiving, transmitting, and processing modes the remaining 1% of the time. In this example embodiment, active operation occurs intermittently, at time intervals similar to those associated with bubble-up events of utility meter endpoints 204.

FIG. 4 illustrates several example applications for auxiliary transmitters 220 in the context of the above-described example AMR system 200. Auxiliary transceiver 220a has been installed in coverage area 209a such that its auxiliary coverage area 222a (represented by a dotted line circumscribing auxiliary transceiver 220a) extends into gap 218 sufficiently to provide radio communications with utility meter endpoints 204e and 204f. Auxiliary transceiver 220a also communicates with the AMR infrastructure, as indicated at communications 226a between auxiliary transceiver 220a and intermediate
transceiver 208a. Because auxiliary transceiver 220a is located within coverage area 209a, its radio transceiver can have the same capabilities as the mass-produced radio transceivers included as part of utility meter endpoints 204. One advantage that can be realized is low cost of communications hardware in the auxiliary transceivers. In one embodiment, auxiliary transceiver 220a has the same radio communications hardware as a utility meter endpoint 204. For example, auxiliary transceiver 220a can have the same circuit card subassembly as the one installed in the utility meter endpoints, but different embedded software/firmware.

Auxiliary transceiver 220a communicates wirelessly with utility meter endpoints 204d, 204e, and 204f as respectively indicated at communications 224d, 224e, and 224f. In one embodiment, at a predetermined time interval (such as hourly, daily, weekly, etc.), auxiliary transceiver 220a broadcasts an modulated RF prompting signal directed generally at utility meter endpoints 204 located in its area of coverage 222a. In another embodiment, each prompt is broadcast according to a predetermined time interval, plus or minus a random time interval.

Utility meter endpoints 204d, 204e, and 204f each respond to the prompt by transmitting their consumption and other information destined for utility database 202. Utility meter endpoints 204 transmit their information according to a slotted ALOHA or other suitable mode of transmission. In one embodiment, auxiliary transceiver 220a receives each utility meter’s information and stores it for later transmission. In another embodiment, auxiliary transceiver 220a receives each utility meter’s information and immediately transmits it to the AMR communications infrastructure. One example communications protocol used for such communications is disclosed in U.S. application having serial no. 10/915,706, filed on August 10, 2004, entitled “Data Communications Protocol in an Automatic Meter Reading System.”

Auxiliary transceiver 220a transmits the information obtained from each of the utility meter endpoints 204d, 204e, 204f to the AMR communications infrastructure via communications link 226a, which are received by intermediate transceiver 208a. Communications from auxiliary transceivers 220 to the AMR communications infrastructure are generally referred to herein as communications 226. In one embodiment, transmissions of data communications 226 that are transmitted by auxiliary transceiver 220a are sent according to an ALOHA mode of transmission.

In one embodiment, data communications 226 include separate, discrete transmissions, each corresponding to an individual utility meter’s consumption data.
Thus, according to this embodiment, data communications 226a include three discrete transmissions separated in time and respectively corresponding to each of utility meter endpoints 204d, 204e, and 204f. In a related embodiment, each discrete transmission of communications 226 is in the same format as the bubbling-up transmissions from utility meter endpoints 204. One advantage of such an arrangement is that no changes or special configuring is needed of the AMR communications infrastructure to accommodate auxiliary transceivers 220. Stated another way, by mimicking utility meter transmissions, the auxiliary transceivers remain transparent to the existing AMR communications infrastructure.

In another embodiment, communications 226 include separate, discrete transmissions, each corresponding to an individual utility meter’s data, but each transmission is reformatted to optimize data transmission to intermediate transceiver 208. For example, each transmission can be encoded according to a Bose-Chaudhuri-Hochquenghem (BCH) scheme. In this embodiment, each intermediate transceiver 208 is preconfigured to receive and process transmissions encoded in this format. In a related embodiment, the transmissions can utilize a Manchester-encoding scheme.

In an alternative embodiment, communications 226 are in a single, condensed, transmission. One benefit of condensing the information is a realization of energy savings relative to transmitting the same information in an uncondensed format. In one embodiment, to accommodate this format of communications 226, the intermediate transceivers are configured to handle such communications from other intermediate transceivers 208 (and auxiliary transceivers 220), in addition to handling communications with utility meter endpoints 204.

Auxiliary coverage area 222a includes utility meter endpoints 204e and 204f that are in coverage gap 218, as well as utility meter endpoint 204d that is also located within coverage area 209a. Utility meter endpoint 204d communicates information to intermediate transceiver 208a via communication 205d, which, in one embodiment, is transmitted according to a bubble-up scheme. Hence, in the example system operation described above, information from utility meter endpoint 204d is received twice by the AMR communications infrastructure (first, via communication 205d directly from the utility meter endpoint 204d, and second, via a corresponding one of the discrete transmissions in communications 226a from auxiliary transceiver 220a). In one embodiment, intermediate transceiver 208 does nothing to address the issue of duplicity, and instead forwards each communication to the central transceiver in the usual manner as
if the duplicative communications corresponded to different utility meters. In this embodiment, utility database 202 operates on each of the received communications to sort out the redundant duplicative sets of meter data based on the information contained in each communication, such as a tag identifying the specific utility meter and time stamp. In other embodiments, the sorting takes place at intermediate transceiver 208, or at central transceiver 206.

Auxiliary transceiver 220b is located in coverage gap 216 in order to provide communications service to utility meter endpoint 204j. Auxiliary transceiver 220b has a coverage area 222b that is sufficient to cover the entire coverage gap 216. However, auxiliary transceiver 220b is itself located outside of coverage area 209b. In order to maintain reliable communications with the AMR communications infrastructure via communications 226b between auxiliary transceiver 220b and intermediate transceiver 208b, auxiliary transceiver 220b can be adapted to communicate at a greater range with intermediate transceiver 208b, as compared with a typical utility meter endpoint 204. In one embodiment, installed auxiliary transceiver 220b includes a high-gain directional antenna that is pointed at intermediate transceiver 208b. In another embodiment, auxiliary transceiver 220b is installed on a high pole or tower to avoid obstructions that can affect electromagnetic wave propagation. In another embodiment, auxiliary transceiver 220b has a more powerful RF transmitter amplifier circuit compared to the transmitter amplifier circuit of a typical utility meter endpoint 204.

Auxiliary transceiver 220c is installed to extend AMR communication system coverage beyond the outside boundary of coverage area 209 in order to provide service to utility meter endpoint 204k. Auxiliary transceiver 220c effectively extends AMR communications system coverage to include auxiliary coverage area 222c. In one embodiment, auxiliary transceiver 220c is also configured to communicate with more than one intermediate transceiver to ensure reliable communications with the AMR system communications infrastructure. As illustrated in FIG. 4, auxiliary transceiver 220c communicates with intermediate transceiver 208a via communications 226c1, and with intermediate transceiver 208c via communications link 226c2. In one embodiment, auxiliary transceiver 220c includes an omni-directional antenna and a sufficiently powerful transmitter to reach the intermediate transceivers 208a and 208c. In another embodiment, auxiliary transceiver 220c includes transmitter circuitry driving two distinct high-gain directional antennas, each directed at a corresponding intermediate transceivers 208.
In the example expansion of coverage area 209 illustrated in FIG. 4, auxiliary transceiver 220d is used to extend communications service to utility meter endpoints 204n, 204p, 204q, and 204r, which are all located outside of coverage area 209. Auxiliary transceiver 220d provides an auxiliary coverage area 222d that includes these utility meter endpoints. Auxiliary transceiver 220d is also outside of coverage area 209 and, unlike auxiliary transceiver 220c discussed above; auxiliary transceiver 220d is not within communications range of any intermediate transceiver 208. To facilitate communications between auxiliary transceiver 220d and the AMR infrastructure, auxiliary transceiver 220e is located such that it is within communications range of intermediate transceiver 208b as well as within communications range of auxiliary transceiver 220d. As indicated in FIG. 4, auxiliary transceiver 220e provides an auxiliary coverage area 222e that includes auxiliary transceiver 220d. In one embodiment, auxiliary transceiver 220d includes low-power intermittently operating receiver circuitry that is the same or similar to the circuitry of utility meter endpoints 204. In this embodiment, auxiliary transceiver 220d is programmed to periodically power up, momentarily, in an attempt to detect the presence of a communication signal in a similar operating mode as described above with respect to utility meter endpoint 204 receiver low-power operation.

In an example operation, auxiliary transceiver 220e transmits a prompt according to a preconfigured periodic transmission schedule, and activates its receiver circuitry for reception of data from auxiliary transceiver 220d for a predetermined amount of time sufficient to receive communications responsive to the prompt. In one embodiment the prompt broadcast from auxiliary transceiver 220e is identical to a prompt to which utility meter endpoints 204 are responsive. In this embodiment, auxiliary transceivers 220 are configured to not respond to prompts for a predefined time after issuing a prompt themselves. This feature prevents more than one auxiliary transceiver 220 within communications range of one another from endlessly exchanging prompts. The prompt is included in communications 226d, and is detected by auxiliary transceiver 220d during one of its intermittent signal detection attempts. In response to the prompt, auxiliary transceiver 220d broadcasts a utility meter prompt to utility meter endpoints 204 in its coverage area 222d, and activates its receiver circuitry for reception of data from utility meter endpoints 204 for a predetermined amount of time sufficient to receive communications responsive to the prompt.

In one embodiment, the prompt broadcast from auxiliary transceiver 220e (intended to evoke a response from another auxiliary transceiver 220) is identical to a
prompt to which utility meter endpoints 204 are responsive, such as the prompt broadcast from auxiliary transceiver 220d. In this embodiment, auxiliary transceivers 220 are configured to not respond to prompts for a predefined time after issuing a prompt themselves. In an alternative embodiment, the prompt broadcast from auxiliary transceiver 220e (intended to evoke a response from another auxiliary transceiver 220) includes an indication that distinguishes it from a prompt intended to evoke a response from utility meter endpoints 204. Either of these features prevents an oscillatory situation in which, for example, auxiliary transceivers 220e responds to a prompt from auxiliary transceiver 220d intended for utility meter endpoints 204 by broadcasting a second prompt, to which auxiliary transceiver 220d again responds.

Each of utility meter endpoints 204 within area of coverage 222d responds to the prompt issued by auxiliary transceiver 220d by transmitting its consumption and other information according to a predefined protocol, such as slotted ALOHA mode. Auxiliary transceiver 220d receives each utility meter’s data, and transmits each set of data to auxiliary transceiver 220e. In one embodiment, auxiliary transceiver 220d transmits each set of utility meter endpoint 204 data individually, and in the same format as in which the data was received from the corresponding utility meter endpoint 204.

The present invention may be embodied in other specific forms without departing from the spirit of the essential attributes thereof; therefore, the illustrated embodiments should be considered in all respects as illustrative and not restrictive, reference being made to the appended claims rather than to the foregoing description to indicate the scope of the invention.
What is claimed is:

1. In an automatic meter reading (AMR) communications system having a plurality of endpoints adapted for two-way communications, a plurality of collection transceivers having a communications range that defines a principal coverage area and adapted to receive information from endpoints located in the principal coverage area, a method of improving AMR system coverage comprising:
   providing an auxiliary transceiver in a fixed location, wherein the auxiliary transceiver has a communications range that defines an auxiliary coverage area;
   automatically operating the auxiliary transceiver in a low-power standby mode during a first time duration, and automatically operating the auxiliary transceiver in an active mode during a second time duration that is shorter than the first time duration, wherein operating the auxiliary transceiver during the second time duration includes:
   exiting the standby mode to enter an active operating mode;
   communicating with an endpoint on a prompt-response basis;
   receiving information transmitted from the endpoint located in the auxiliary coverage area in response to the prompt-response communications; and
   transmitting at least a subset of the received endpoint information to at least one of the plurality of collection transceivers.

2. The method of claim 1, wherein the plurality of collection transceivers include transceivers selected from the group consisting of: an intermediate transceiver, a central transceiver, or a combination thereof.

3. An automatic meter reading (AMR) system, comprising:
   a plurality of utility meter endpoints, wherein each of the utility meter endpoints includes a radio-frequency (RF) transceiver adapted for transmitting endpoint information based on a prompt-response mode of communication;
   a plurality of intermediate transceivers having a communications range that defines a principal coverage area, each intermediate transceiver adapted to receive endpoint information from utility meter endpoints located within a corresponding portion of the principal coverage area;
   a central transceiver adapted to communicate with each of the intermediate transceivers and to collect endpoint information; and
an auxiliary transceiver having a communications range that defines an auxiliary coverage area, wherein the auxiliary transceiver is adapted to automatically engage in communication with utility meter endpoints in the auxiliary coverage area based on the prompt-response mode of communication, and adapted to automatically transmit received endpoint information to at least one of the plurality of intermediate transceivers.

4. The auxiliary transceiver according to claim 1 or 2, wherein the auxiliary transceiver is adapted to operate without any connection to an external power source.

5. The auxiliary transceiver according to any preceding claim, wherein the auxiliary transceiver is adapted to automatically communicate with at least one preexisting transceiver without reconfiguration of the at least one preexisting transceiver.

6. An auxiliary transceiver for use with an automated meter reading (AMR) system, the auxiliary transceiver comprising: a radio frequency (RF) receiver circuit, a RF transmitter circuit, a processor coupled with the RF receiver and the RF transmitter circuits, and a battery adapted to supply energy to the RF receiver, RF transmitter, and CPU circuits without externally-supplied power; the auxiliary transceiver characterized in that:

   the processor executes a program that causes the auxiliary transceiver to:

   during a first time duration, automatically operate in a low-power standby mode and, during a second time duration that is shorter than the first time duration, automatically:

   exit the standby mode to enter an active operating mode;
   respond to an RF prompt;
   receive endpoint information;
   transmit at least a subset of the received endpoint information; and
   exit the active operating mode to return to the low-power standby mode.

7. A method of operating an auxiliary transceiver according to any preceding claim, wherein the prompt includes communicating a command and control frame.

8. A method of operating an auxiliary transceiver according to any preceding claim,
wherein the endpoint information includes metered data, and wherein operation during the second time duration includes re-formatting the metered data.

9. The auxiliary transceiver according to any preceding claim, wherein the auxiliary transceiver includes circuitry substantially similar to circuitry of a utility meter endpoint.

10. The auxiliary transceiver according to any preceding claim, wherein the active operating mode is entered into at randomized time intervals.
Fig. 3

302 Configure and install the auxiliary transceiver in the field

304 Send out prompt on assigned RF channel

306 Turn on receiver and listen for X seconds for any responses to the broadcast prompt.

Yes 308 Receive any messages?

302

No 308

310 Store received messages in memory

Yes 308

312 Pause

No 308

322 Time for next activation?

Yes 318 Pull the next message out of memory, transmit the message, delete message from memory

No 322

320

322

316 Are there more messages in memory?

Yes 314 Pull the first message out of memory, transmit the message, delete message from memory

No 316
# PATENT COOPERATION TREATY
## PCT
### INTERNATIONAL SEARCH REPORT

(PCT Article 18 and Rules 43 and 44)

<table>
<thead>
<tr>
<th>Applicant's or agent's file reference</th>
<th>FOR FURTHER ACTION</th>
<th>see Form PCT/ISA/220 as well as, where applicable, item 5 below.</th>
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<tr>
<td>1725.135WO02</td>
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<td>International application No.</td>
<td>International filing date (day/month/year)</td>
<td>(Earliest) Priority Date (day/month/year)</td>
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<td>Applicant</td>
<td>ITRON, IC.</td>
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</table>

This international search report has been prepared by this International Searching Authority and is transmitted to the applicant according to Article 18. A copy is being transmitted to the International Bureau.

This international search report consists of a total of [ ] sheets.

[ ] It is also accompanied by a copy of each prior art document cited in this report.

1. **Basis of the Report**
   a. With regard to the **language**, the international search was carried out on the basis of:
      - [x] the international application in the language in which it was filed.
      - [ ] a translation of the international application into ________________, which is the language of a translation furnished for the purposes of international search (Rules 12.3(a) and 23.1(b))
   b. [ ] With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, see Box No. I.

2. [ ] Certain claims were found unsearchable (See Box No. II)

3. [ ] Unity of invention is lacking (See Box No. III)

4. With regard to the **title**, the text is approved as submitted by the applicant.

   [ ] the text has been established by this Authority to read as follows:

   **Receiver for an automated meter reading system**

5. With regard to the **abstract**, the text is approved as submitted by the applicant.

   [x] the text has been established, according to Rule 38.2(b), by this Authority as it appears in Box No. IV. The applicant may, within one month from the date of mailing of this international search report, submit comments to this Authority.

6. With regard to the **drawings**,
   a. the figure of the **drawings** to be published with the abstract is Figure No. 1
      - [x] as suggested by the applicant.
      - [ ] as selected by this Authority, because the applicant failed to suggest a figure.
      - [ ] as selected by this Authority, because this figure better characterizes the invention.
   b. [ ] none of the figures is to be published with the abstract.
NEW ABSTRACT

An automatic meter reading (AMR) system is shown in Figure 1. The system has a plurality of endpoints (204) for bi-direction communications, a plurality of collection transceivers with a range that defines a principle coverage area (209a-209c) for receiving information from the endpoints, and a utility database (202) for storing some of the received information. The AMR system coverage can be improved by providing auxiliary transceivers (220a-220c) in a fixed location such that the coverage of the auxiliary covers areas not within the principle coverage areas of the collection transceivers. The auxiliary transceivers operate in a low power mode and communicate information received from endpoints to the collection transceivers.
INTERNATIONAL SEARCH REPORT

A. CLASSIFICATION OF SUBJECT MATTER
IPC: G08C 19/20(2006.01)

USPC: 340/870.03
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED
Minimum documentation searched (classification system followed by classification symbols)
U.S.: 340/870.03, 870.02

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
Please See Continuation Sheet

C. DOCUMENTS CONSIDERED TO BE RELEVANT

<table>
<thead>
<tr>
<th>Category</th>
<th>Citation of document, with indication, where appropriate, of the relevant passages</th>
<th>Relevant to claim No.</th>
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<tr>
<td>A</td>
<td>US 5,896,097 A (CARDOZO) 20 April 1999</td>
<td>1-2 and 6</td>
</tr>
<tr>
<td>A</td>
<td>US 5,438,329 A (GASTOUNIOTIS et al) 01 August 1995</td>
<td></td>
</tr>
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</table>

Further documents are listed in the continuation of Box C. See patent family annex.

Date of the actual completion of the international search
20 July 2006 (20.07.2006)

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Form PCT/ISA/210 (second sheet) (April 2005)
Continuation of B. FIELDS SEARCHED Item 3:

EAST

search terms: auxiliary, transceiver, relay, meter, utility, electrical, cell, sleep, dead spots, coverage, area, amr, network