

IMPROVEMENTS TO AN AD-HOC SYSTEM AND A METHOD THEREOF

FIELD OF THE INVENTION

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The present invention relates to an ad-hoc system and more particularly, the present invention relates to improvements to the said ad-hoc system and a method thereof.

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BACKGROUND OF THE INVENTION

To collect accurate real-time energy consumption information of a building presently utilizes cabled networks of various protocols and transmission technologies (CAT5 TCP/IP, power line LON Works, etc), it is often only cost-effective to put in a sensor/ actuator network during the construction/ fabrication or retrofit phase of a facility, when cabling does not require tearing out and re-instatement of existing structure. Thus it will be expensive to enable facilities constructed in the 1980s and before to enjoy the benefits of such networks.

The average lifespan of a facility in the developed world is 100 years while in developing or newly industrialized countries, it is closer to 30 years.

This explains why the majority of the buildings, especially in developed countries, *counter-intuitively* do not have a sensor/ actuator network in place.

In the past decade, alternate solutions that make use of wireless technologies have been proposed, and in some cases implemented to circumvent the cabling constraint.

The first classes of networks are those governed by the popular IEEE 802.11 protocols, such as WiFi. However, 802.11 technologies require static access points/ routers connected by physical cabling, and individual wireless nodes are incapable of routing information. As the wireless network can easily be occluded by physical material such as reinforced concrete or steel, the setup of a usable topology might require access points (and thus cabling) in many spots, thus limiting the practicality of the solution.

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The second class of networks is that making use of wide area wireless technologies such as CDMA or GPRS. In this case, relatively low bandwidth and reliability, network occlusion (necessitating installation of repeaters), telecommunications costs and security concerns often limit the applicability of such solutions.

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The third and most promising class of networks is the ad-hoc wireless networks, which was first proposed by the Massachusetts Institute of Technology, also commonly known as *Mesh* networks. These networks

(there are around 70 competing protocols broadly classified into table-driven and demand-driven protocols) have the advantage of having each node serve as a router that can detect and join existing networks, as well as compute optimal transmission paths. This means that Mesh networks are highly
5 adaptable to a constantly changing topology, self-healing, and easily scalable with minimal requirements on cabling. The problem of using Mesh networks as sensor/ actuator networks is that Mesh technologies are designed for generic networking purpose, i.e. they must also function well, for example, as an office network. As a result, each node has to have significant processing
10 power (since it is a complete router), thus making the cost of the node relatively high. Certain protocol classes, such as Zigbee, also suffer from limitations of scalability (e.g. can only accommodate up to 256 nodes per network).

15 Some prior art would now be briefly discussed herewith.

Firstly, US Patent No. 6,895,347 relates to a number of approaches for operating data loggers. More particularly, this patent relates to software techniques for controlling critical functions of a low-power-battery-operated
20 data logger. In this patent, a first approach is by initializing numerous memory locations when a new firmware is detected. Another approach would allow a processor system of a data logger to receive a high baud rate data stream while being operated in a sleep mode. Another approach provides an estimation of the remaining battery capacity of a data logger's primary power

source. Finally, an approach is also provided for protecting volatile variables during a disruption of primary power. In other words, this patent teaches an approach, which utilizes wired software procedures for data acquisition by a data logger. In comparison with the present invention, the present invention
5 relates more to a wireless connected data logger.

US patent No. 6965575 relates to a device and method for determining an optimal route based upon path quality of routes to an access node of a wireless mesh network. The method in this patent includes receiving routing
10 packets at the access node through at least one wireless route, in which it further includes route information that identifies the wireless route of the routing packet. This patent also teaches that a wireless route having a greatest success ratio is first. In other words, quality of connections is important to derive routing paths by utilizing the Mesh Network Nodes. In
15 comparison of the present invention, the present invention does not utilize such configuration.

US patent No. 6856592 relates to a method of providing restoration routes for protecting traffic in a mesh network. Further to this, the said method
20 comprises the steps of generating a set of eligible restoration routes for each span in the network, establishing a bi-criteria objective function in terms of route length and capacity cost for selecting a set of restoration routes, and selecting a set of restoration routes for each span from the eligible restoration routes in dependence upon the bi-criteria objective function. However, utilizing

such configuration would just be too hard on the servers. Therefore, the present invention adopts a different approach.

US patent No. 5606551 relates to a communication a bi-directional
5 mesh network. The said network includes a plurality of communication loops
in which each comprising a plurality of nodes interconnected to one another
by bi-directional communication links. The said invention also includes a
switch to transfer packets from one communication loop to another
communication loop, and vice versa, as a function of destination addresses
10 contained in the packets. However, the present invention adopts a server
operated MESH network.

US patent No. 6850502 relates to a join process for a wireless mesh
topology network. The join process adds a joining node to the network and
15 includes having the joining node listen to sub-sectors at a specific receiving
frequency for a defined time. Thereafter, the network node changes its sub
sectors and its receiving frequencies according to a defined timing and
sequence. In the present invention, no such configuration is utilized.

20 US patent No. 6363062 relates to a wireless mesh topology data
communications network. A portion of the protocol is synchronous using a
schedule of control channel sessions held at all mutually communicating
nodes of the network and a portion of the protocol is asynchronous, relying
upon gaps between control channel sessions for transmission of requested

data. This patent basically can be used as a reference to the present invention for discussion purpose.

US patent No. 6959311 relates to a technique of logging full updates to
5 a plurality of data records into discrete pages in non-volatile storage. In other words, this patent relates to a means of storing data for future reference. In the present invention full data logging is not require as all data would be saved on to a server for further use.

10 US patent No. 5502656 relates to a data logger, which includes a pre-programmed Erasable Programmable Read Only Memory (EPROM) and a Random Access Memory (RAM). The said RAM being adapted to accept instructions on the sensor driver to evoke a desired sample regime. This patent further relates to a method of doing so. However, the present invention
15 is designed and configured to utilize commercially available data logger and is not subject to this prior art document.

US patent No. 6917759 relates to a shared mesh protection scheme. This patent further relates to a protection path definition. When a failure is
20 detected, the network using an overhead byte message will inform the routing source network element of the connection of the failure in the working path. Therefore, once the failure has occurred the source elements will send messages using overhead bytes to the corresponding network elements along the protection path. Accordingly, routing tables located at the switch card of

the network elements, set-up when the working path connections were initially established, determine this dynamically allocated protection path environment. The advantage of this patent is that it requires a big amount of power to operate and its not economically feasible.

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US patent No. 6879574 relates to a standalone ad-hoc network cells which are used as an extension of the backbone infrastructure in terms of network architecture or/and its service capabilities. Further to this, these ad-Hoc networks will integrate to the Internet via a cellular or other access
10 networks. In other words, this patent teaches a configuration and communication method between a remote device and a MESH Network. The disadvantage of such configuration would be the increase in cost due to the usage of a remote device such as a mobile, PDA and the like. Another disadvantage is that it is not practical as not all mobile like device would have
15 network signal for the data logger location.

US patent No. 6725401 relates to a failure within a communications network. Such failures are compensated by establishing a set of two or more communications paths across the network between a source node and a
20 destination node. The disadvantage of this patent is that the system would require a higher bandwidth and processing configuration.

US patent No. 6252884 relates to a system and process for automatically and dynamically configuring a wireless computer network. In

this patent, the system is designed in such that each computer that is to contribute in the dynamic network continuously broadcasts its address to any other computer within range of the wireless network hardware. Briefly, this patent relates to a management strategy for dynamic wireless network, i.e. not static network. On the other hand, the difference is obvious that the present invention relates more to a static wireless network.

US patent No. 6791949 teaches a method for establishing and maintaining a wireless ad hoc network comprising backbone nodes which forward packets through the network and non-backbone nodes which are capable of using the network, but do not forward packets. In the present invention, requirement for bandwidth only involves the server and this is done particularly during initial setup or during the adding of a new node or when removing a node.

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US published patent No. 20060031576 relates to a method for updating routing tables in ad-hoc networks (AHN), such as networks including mobile nodes communicating via wireless links, are disclosed. The method utilizes both stochastic and empirical information for updating routing tables at loss or gain of neighbor nodes. In comparison of the present invention, the configuration is such that the design of the protocol is configured to assume changes of low probability in network nodes. Further to this, in the present invention, updating is manually done or when a broken link is detected.

US published patent No. 20050063313 relates to and is similar in technology one way or another to the earlier mentioned US patent No. 6791949. However, even though the main nodes in a cluster is similar to the present invention, the main nodes are determined and selected from a group
5 of nodes by utilizing algorithm and wherein the nodes in the server are pre-determined.

US patent No. 5987011 and US published patent No. 20050030921 in general is a write up discussing the ad-hoc network protocol for better
10 understanding and how the system operates.

Any discussion of documents, devices, acts or knowledge in this specification is included to explain the context of the invention. It should not be taken as an admission that any of the material forms a part of the prior art
15 base or the common general knowledge in the relevant art in Singapore or elsewhere on or before the priority date of the disclosure and claims herein. All statements as to the date or representation as to the contents of these documents is based on the information available to the applicant and does not constitute any admission as to the correctness of the dates or contents of
20 these documents.

Therefore, it is the objective of the present invention to provide a technology that could be used as a setup and maintenance and which is cost-

effective, highly scalable and reliable ad-hoc wireless sensor/ actuator networks.

It is yet another objective of the present invention to introduce a simple
5 and low cost ad-hoc wireless network for applications that have moderate or low frequency adding and/or removing nodes to/from the network.

One advantage of the present invention over the prior art is that as compare to wired and WiFi networks, the present invention removes the
10 requirement of cables which makes retrofitting of existing facilities much easier.

Another advantage of the present invention is that the node does not act as a router. Therefore, the amount of power and cost incurred is much
15 lesser than Mesh Network nodes.

A further advantage of the present invention is that the tabulation of optimal dynamic routing table is done at the server during the initial setup or during the adding of new nodes and/or when removing existing nodes. This
20 will thereafter alleviate the processing power of the network nodes. This will further reduce the power required to operate the network nodes, as compare to the prior art.

SUMMARY OF THE INVENTION

The present invention relates to an improvement to an ad-hoc system and a method thereof. The improvement comprises of a server, a plurality of
5 devices namely a node, a data logger and an ad-hoc wireless network gateway. The server is configured and designed to manage a list of connected nodes and apply a shortest path algorithm to generate the optimal routing path between the server and each connected node. This process is triggered whenever the list of connected nodes changes. The server is also
10 designed to periodically polls energy consumption readings from the tracked nodes based on a preset sampling interval and in which these readings will be stored in a data store, for example a database table, for future generation of trend analysis reports and energy consumption forecasts. Further improvement is that the server is configured to track and alert the system
15 administrator of any node failure cellular text messaging and/or emails. The node has an embedded and programmable wireless network chip that supports IEEE 802.15.4 protocols to define the routing and communication protocols between the server and the nodes within the ad-hoc wireless network.

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Each of the network nodes will be connected to a COTS data logger via a serial/USB connection in which wherein the data logger is an automated instrument that records energy consumption readings. The data loggers could be selected from an electric data logger and/or a temperature data logger

and/or water level/usage data logger. The ad-hoc wireless network gateway is the gateway interface between the server and the nodes and wherein it is configured to act as a switch/bridge in the ad-hoc wireless network and wherein each ad-hoc wireless network node will be able to route/relay among its' parent or neighboring nodes.

The process in which the server discovers the network structure and optimizing the routing path from the server to each node, in which the method comprises the steps of:

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(a) The server will broadcast a request for nodes to respond with Node Identification,

(b) The immediate nodes to the server will respond with a reply.

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The immediate nodes will also relay the broadcast request to neighboring nodes and so on.

(c) Each of the immediate nodes will then help relay any newly discovered neighboring replies to the server and wherein before relaying, the node will update the cost of the relay by increasing the number of Hops and updating the relay time.

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(d) Upon receipt of any replies from nodes, the server will store the nodes information preferably in a temporary data store, which may be a data table and wherein the server will keep listening for reply packets until there is no new node's reply and wherein

once all the nodes' information is captured, the server will broadcast a "Stop Beacon" signal.

(e) Upon receiving "Stop Beacon" signal, all the nodes in the ad-hoc wireless network will stop relaying any packets.

5 (f) The server will then start processing the nodes information and this will be transform into the input format of an efficient optimal shortest path algorithm and wherein said algorithm will be executed on the formatted input and wherein the output of this algorithm will be the optimal routing path from the server to each
10 node.

(g) The generated routing tables will be stored in the server data store and broadcast in the ad-hoc wireless network.

(h) The temporary storage is cleared.

15 When the node receives the routing tables, it will only capture and store the routing information that is applicable to it self which preferably would be its parent node and assigned immediate/child nodes. Upon receiving its routing information, each node will send a "ACK" beacon to the server to acknowledge receipt of the routing information. When all the nodes received
20 the routing information, the server will be in the ready state to periodically poll readings from the tracked nodes' data loggers.

A method according to the invention, which comprises the process in which the server will re-compute optimal routing table when there are changes

in the ad-hoc wireless network structure and wherein the method comprises the steps of:

- (a) Server will broadcast a "ALIVE" request for each node to respond that it is "ALIVE".
- 5 (b) Upon receipt of the "ALIVE" request, a node will respond with an "ALIVE" beacon signal and wherein each node will also relay any "ALIVE" beacon signal from its dependent neighboring nodes.
- 10 (c) Nodes that are having problems sending "ALIVE" reply packet to its parent node will indicate in their packet that there are problems sending to their parent node and wherein the neighboring node(s) of these nodes will help to relay these "ALIVE" reply messages.
- 15 (d) The server will capture and store any node's "ALIVE" reply to a temporary data store.
- 20 (e) Once there are no more new "ALIVE" replies, the server will generate a list of nodes that failed to respond and an alert notifications of the nodes that failed to respond with "ALIVE", excluding the nodes that are manually removed by the system administrator, will be sent to the system administrator.
- (f) The server will use the updated list of nodes information as the input to the optimal shortest path algorithm and wherein a node and network load balancing will also be applied to generate the new optimal routing path from the server to each node.

- (g) This updated routing table will be updated to the server and the temporary storage used to capture “ALIVE” messages will be cleared.
- (h) This updated routing table will be broadcasted across the ad-hoc wireless network.
- (i) When a node receives the updated routing information, it will capture and store the routing information that is relevant to it self and this will include its parent and assigned immediate neighboring nodes and wherein a “ACK” message will be sent back to the server to indicate receipt of the updated routing information.
- (j) Once all the nodes receive and update their routing information, the server will be in the ready state to periodically poll readings from the tracked nodes’ data loggers.

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A method according to the invention which illustrates the process in which the server periodically poll readings from the tracked nodes’ data logger, and wherein the method comprises the steps of:

- (a) The server sends a “Read Value” request packet to the first node of the routing path of the target node.
- (b) When the first node receives the “Read Value” request packet, it will check if the packet is designated to itself and if yes, it will call the data logger API to get the current reading

and wherein said reading will be time-stamped and sent back to the server via its parent node.

(c) If the "Read Value" request packet is not for itself, it will relay the message to the next node specified in the routing path.

5 (d) Once the server received the readings, it will store the values of the readings and timestamps to its data store.

(e) In the event of time-out in receiving the targeted node's respond, the ad-hoc wireless network maintenance process will be activated.

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Other aspects and preferred aspects are disclosed in the specification and / or defined in the appended claims, forming a part of the description of the invention.

15 Further scope of applicability of the present invention will become apparent from the detailed description given hereinafter. However, it should be understood that the detailed description and specific examples, while indicating preferred embodiments of the invention, are given by way of illustration only, since various changes and modifications within the spirit and
20 scope of the invention will become apparent to those skilled in the art from this detailed description.

BRIEF DESCRIPTION OF THE FIGURES

Further disclosure, objects, advantages and aspects of the present application may be better understood by those skilled in the relevant art by
5 reference to the following description of preferred embodiments taken in conjunction with the accompanying drawings, which are given by way of illustration only, and thus are not limitative of the present invention, and in which:

10 Figure 1 shows a diagrammatic view of the present invention in general;

Figure 2 shows a block diagram of a method according to the present invention;

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Figure 3 shows a block diagram of another method according to the present invention; and

Figure 4 shows a block diagram of another method according to the
20 present invention.

DETAILED DESCRIPTION OF THE PRESENT INVENTION

The present invention will now be described in detail with references made to the accompanied figures but not limited to thereto.

5

Reference is first made to Figure 1 wherein the present invention comprises of a server (10), a plurality of devices namely a node (12), a data logger (14) and an ad-hoc wireless network gateway (16), hereinafter also refers as ad-hoc.

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According to the present invention, the central server (10) is configured and designed to control four main roles. One of the server's (10) roles is to manage a list of connected nodes and apply a shortest path algorithm to generate the optimal routing path between the server and each connected
15 node. It should be noted that this process is triggered whenever the list of connected nodes changes. The server is also configured and designed to periodically poll energy consumption readings from the tracked nodes based on the preset sampling intervals. These readings will thereafter be stored in a data store or data bank for future use. Some of the usage could be directed to
20 trend analysis reports and energy consumption forecasts. The server (10) is further configured and designed to track and send an alert to a system administrator of any node (12) failure. These notification messages could be sent via Cellular text Messaging (Short Message Send [SMS]) and/or emails or in any other formats know in the art.

According to the present invention the node (12) includes an embedded and programmable wireless network chip, which supports IEEE 802.15.4 protocols. Reference is now made to an Open System Interconnection (OSI) model, in which the 'Layer 5' (Session) and the above protocols are preferably configured and programmed by using C/C++/C# and the provided chip is of API. This configuration or arrangement would define the routing and communication protocols between the server and the nodes within the ad-hoc wireless network. A common interface protocol for COTS (Commercial Off-The-Shelf) data logger (14) will also be embedded into the chip.

In the present invention, each network node will be connected to the COTS data logger (14) via a serial/USB connection or any other known connection in the art. A data logger (14) according to the present invention is preferably an automated instrument that records energy consumption readings. APIs are typically exposed to support reading of current values, reading of historical values and setting of sampling intervals. Some examples of data loggers that are shown in Figure 1 are as follow:

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a. Electric Data Logger (18)

This data logger (18) particularly measures the current (amps) and voltage (volts) which may be used to derive Kilo Watts (KW)

NB: (KW) = (amps x volts) / 1000

b. Temperature Data Logger (20)

5 This data logger (20) measures the temperature of the tracked location. The temperature is measured in degree Celsius ($^{\circ}\text{C}$) or Fahrenheit ($^{\circ}\text{F}$).

c. Water Level/Usage Data Logger (22)

10 This data logger (22) measures the water consumption in Liters (L), cubic meters (m^3) or gallons (gal).

According to the present invention, the ad-hoc wireless network gateway (16) is the gateway interface between the server (10) and the nodes (12). This gateway (16) acts as a switch or bridge in the ad-hoc wireless network. In the present invention the server (10) may be connected directly or
15 indirectly via Ethernet to the ad-hoc (16). By having routing capabilities, each ad-hoc wireless (16) network node (12) will be able to route or relay among its' parent or neighboring nodes (12). As the IEEE802.15.4 compliant chip supports either 16 or 32 bits addressing, this invention does not have the 255 nodes limit constrained by Zigbee wireless network. Therefore, theoretically
20 there can be a maximum of 65,536 and 4.2 Million nodes in the ad-hoc wireless networks. This enables the present invention to be adopted in facilities of any size. It should be noted that in an energy management system, the number of tracked nodes (12) is typically in the order of 100 to 10,000.

In contrast to Mesh Network Nodes, the nodes (12) do not compute routing table, thus the amount of power and cost to operate is lesser than Mesh Network nodes. The dynamic routing table will be computed and
 5 optimized by the server during the initial setup, addition of new nodes and removal of existing nodes. This optimal routing table will be broadcast across the network. The nodes (12) will only store and use the relevant routing path. Since the changes in network structure are usually moderate to low, this broadcast frequency is relatively low.

10

Reference is now made to Figure 2 wherein is illustrates therein the process in which the central server (10) determines the network structure and optimize the routing path from the server (10) to each node (12). The following are the protocol steps for this discovery process:

15

Pre-condition: Server (10) is set to initial setup phase/path discovery is activated by the System Administrator.

1. Server (10) is configured to broadcast a request for nodes (12) to
 20 respond with a Node Identification.

2. Then the immediate nodes (12) to the server (10) will respond with a reply (packet encapsulated with Node's IDs and related costs like Hops

to the server (10) and routing time). The immediate nodes (10) will also relay the broadcast request to neighboring nodes (10) and so on.

- 5 3. Then each of the immediate nodes (12) will help relay any newly discovered neighboring replies to the server (10). However, before relaying, the node (12) will update the cost of the relay by increasing the number of Hops and updating the relay time.
- 10 4. In this step, upon receipt of any replies from nodes (12), the server (10) will store the nodes (12) information in a temporary data store. The server (10) will keep tracking for reply packets until there is no new node's reply. Once all the nodes' (14) information is captured, the server (10) will broadcast a "Stop Beacon" signal.
- 15 5. Then, upon receiving the "Stop Beacon" signal, all the nodes (12) in the ad-hoc wireless network (16) will stop relaying any packets.
- 20 6. Then the said server (10) will begin processing the nodes (12) information (IDs, Hops and time of routing). This will later be transform into an input format of an efficient optimal shortest path algorithm. This algorithm will be executed on the formatted input. The output of this algorithm will be the optimal routing path from the server (10) to each node (12). It should be noted that the node (12) and network load

balancing should also be taken into consideration when generating the optimal routing path.

5 7. Then, the generated routing tables will be stored in the server (10) data store and would be broadcasted in the ad-hoc wireless network (16).

8. Then the temporary storage is cleared thereto.

10 9. When a node (12) receives the routing tables, it will only capture and store the routing information that is applicable to itself, i.e. that will be its parent node (12) and assigned immediate nodes (12). It should be noted that a parent node (12) is a node that is closer to the server (10). In this invention, each node (12) does not need to store routing information to all other nodes (12) in the network. This greatly reduces
15 the storage requirements of the node (12) routing information.

20 10. Upon receiving its routing information, each node (12) will send an "ACK" beacon to the server (10) to acknowledge receipt of the routing information.

11. Once all the nodes (12) receive the routing information, the server (10) will be in a ready state to periodically poll readings from the tracked nodes' (14) data loggers.

Post-conditions: Optimal routing path from server (10) to each node (12) would be generated and these routing paths will be stored in the server (10) data store. Additional to this, the nodes (12) will store self-routing path on to the server (10).

5

Reference is now made to Figure 3 wherein illustrates the process in which the server (10) will re-compute optimal routing table when there are changes in the ad-hoc wireless network (16) structure.

10 Pre-conditions: Removal of node (12) or failure to respond from node (12).

1. The server will broadcast an "ALIVE" request for each node (12) to respond to.

15

2. Upon receipt of the "ALIVE" request, a node (12) will respond with an "ALIVE" beacon signal. Said node (12) will also relay any "ALIVE" beacon signal from its dependent neighboring nodes (12) to the server (10).

20

3. Then, nodes (12) with difficulties in sending the "ALIVE" reply packet to their parent node (12) would indicate in their packet that there is some difficulties in sending a reply to their parent node (12).

The neighboring node(s) (12) of these nodes (12) will then help to relay these “ALIVE” replies to the server (10).

4. The server (10) will thereafter capture and store said replies into a temporary data store.
5. Once the server (10) do not receive any “ALIVE” replies, the server (10) will generate a list of nodes (12) that failed to respond. An alert notification of the nodes (12) that failed to respond with “ALIVE”, excluding the nodes (12) that are manually removed by the system administrator, will be sent to the system administrator.
6. The server (10) would then use the updated list of nodes (12) information (IDs and Costs-Hops and Time or relay) as an input to determine the optimal shortest path algorithm. Node (12) and network load balancing will also be applied to generate the new optimal routing path from the server to each node (12).
7. This new routing table will be updated onto the server (10) and the temporary storage, which was used to capture the “ALIVE” messages, would be cleared.
8. Then the updated routing table would be broadcasted across the ad-hoc wireless network (16).

9. When a node (12) receives the updated routing information, it will capture and store the routing information that is relevant only. This would preferably include the parent and assigned immediate
 5 neighboring nodes (12). An “ACK” message will be sent back to the server (10) to indicate receipt of the updated routing information.

10. Once all the nodes (12) receive and updates' their routing information, the server (10) would be now in a ready state to
 10 periodically poll readings from the tracked nodes' (12) data loggers.

Post-conditions: The optimal routing path from the server (10) to each node (12) is updated. These routing paths will be stored in the server (10) data store and the nodes (12) will store its updated routing path to the server
 15 (10).

Reference is made now to Figure 4 wherein illustrates the process in which the server (10) would periodically poll readings from the tracked nodes' (12) data logger (14).

20

Pre-conditions: A service timer of a tracked node (12) is triggered.

1. The server (10) would send a “Read Value” request packet to the first node (12) in the routing path of the target node (12).

2. When the first node (12) receives the “Read Value” request packet, it will determine whether the packet is designated to itself or not. If it is, it will call for the data logger (14) API to obtain the current reading. This reading will be time-stamped and sent back to the server (10) via its parent node (12).
5
3. If it's a no, then it will relay the message to the next node (12) specified in the routing path.
10
4. Once the server (10) receives the readings, it would then store the values of the readings and the timestamps onto its data store.
5. In the event of time-out in receiving the targeted node's (14) respond, the ad-hoc wireless network's (16) maintenance procedure would be thereafter activated.
15

Post-conditions: The server (10) will store values and timestamps of readings in its data store. The data logger/node would store the readings in its cache memory. The timer for server's (10) thread of the target node (12) will be reset and activated to a sleep mode. This thread would be reactivated when the timer expires.
20

According to the present invention, the server's (10) data store will contain both historical and current real time energy consumption trends. A plurality of reporting tools may be used to generate trending reports for further or future analysis. This trending could be used to analyze the energy
5 consumption patterns and devise steps to save energy and thus to save utilities cost.

While this invention has been described in connection with specific embodiments thereof, it will be understood that it is capable of further
10 modification(s). This application is intended to cover any variations uses or adaptations of the invention following in general, the principles of the invention and including such departures from the present disclosure as come within known or customary practice within the art to which the invention pertains and as may be applied to the essential features hereinbefore set forth.

15

As the present invention may be embodied in several forms without departing from the spirit of the essential characteristics of the invention, it should be understood that the above described embodiments are not to limit the present invention unless otherwise specified, but rather should be
20 construed broadly within the spirit and scope of the invention as defined in the appended claims. Various modifications and equivalent arrangements are intended to be included within the spirit and scope of the invention and appended claims. Therefore, the specific embodiments are to be understood to be illustrative of the many ways in which the principles of the present

invention may be practiced. In the following claims, means-plus-function clauses are intended to cover structures as performing the defined function and not only structural equivalents, but also equivalent structures. For example, although a nail and a screw may not be structural equivalents in that
5 a nail employs a cylindrical surface to secure wooden parts together, whereas a screw employs a helical surface to secure wooden parts together, in the environment of fastening wooden parts, a nail and a screw are equivalent structures.

10 “Comprises/comprising” when used in this specification is taken to specify the presence of stated features, integers, steps or components but does not preclude the presence or addition of one or more other features, integers, steps, components or groups thereof.”

CLAIMS

1. An improvement to an ad-hoc system and a method thereof characterized in that wherein the improvement comprises of a server
5 (10), a plurality of devices namely a node (12), a data logger (14) and an ad-hoc wireless network gateway (16) and wherein the server (10) is configured and designed to manage a list of connected nodes (12) and apply a shortest path algorithm to generate the optimal routing path between the server (10) and each connected node (12) and
10 wherein this process is triggered whenever the list of connected nodes (12) changes and wherein the server (10) is also designed to periodically polls energy consumption readings from the tracked nodes (12) based on a preset sampling interval and in which these readings will be stored in a data store, for example a database table, for future
15 generation of trend analysis reports and energy consumption forecasts and wherein further improvements is that the server (10) is configured to track and alert the system administrator of any node (12) failure cellular text messaging and/or emails.
- 20 2. An improvement to an ad-hoc system and a method as claimed in Claim 1 wherein the node (12) has an embedded and programmable wireless network chip that supports IEEE 802.15.4 protocols to define the routing and communication protocols between the server (10) and the nodes (12) within the ad-hoc wireless network (16).

3. An improvement to an ad-hoc system and a method as claimed in Claim 1 wherein each of the network nodes (12) will be connected to a COTS data logger (14) via a serial/USB connection in which wherein
5 the data logger (14) is an automated instrument that records energy consumption readings.
4. An improvement to an ad-hoc system and a method as claimed in Claim 3 wherein the data loggers (14) could be selected from an
10 electric data logger (18) and/or a temperature data logger (20) and/or water level/usage data logger (22).
5. An improvement to an ad-hoc system and a method as claimed in Claim 1 wherein the ad-hoc wireless network gateway (16) is the
15 gateway interface between the server (10) and the nodes (14) and wherein it is configured to act as a switch/bridge in the ad-hoc wireless network and wherein each ad-hoc wireless (16) network node (12) will be able to route/relay among its' parent or neighboring nodes (14).
- 20 6. A method according to the invention as claimed in Claim 1 which comprises the process in which the server (10) discovers the network stricture and optimizing the routing path from the server (10) to each node (12), in which the method comprises the steps of:

- a. The server (10) will broadcast a request for nodes (12) to respond with Node Identification,
- b. The immediate nodes (12) to the server (10) will respond with a reply. The immediate nodes (10) will also relay the broadcast request to neighboring nodes (10) and so on.
- c. Each of the immediate nodes (12) will then help relay any newly discovered neighboring replies to the server (10) and wherein before relaying, the node (12) will update the cost of the relay by increasing the number of Hops and updating the relay time.
- d. Upon receipt of any replies from nodes (12), the server (10) will store the nodes (12) information preferably in a temporary data store, which may be a data table and wherein the server (10) will keep listening for reply packets until there is no new node's reply and wherein once all the nodes' (12) information is captured, the server (10) will broadcast a "Stop Beacon" signal.
- e. Upon receiving "Stop Beacon" signal, all the nodes (12) in the ad-hoc wireless network (16) will stop relaying any packets.

f. The server (10) will then start processing the nodes (12) information and this will be transform into the input format of an efficient optimal shortest path algorithm and wherein said algorithm will be executed on the formatted input and wherein the output of this algorithm will be the optimal routing path from the server (10) to each node (12).

g. The generated routing tables will be stored in the server (10) data store and broadcast in the ad-hoc wireless network (16).

h. The temporary storage is cleared.

7. A method as claimed in Claim 6 wherein when the node (12) receives the routing tables, it will only capture and store the routing information that is applicable to itself which preferably would be its parent node (12) and assigned immediate/child nodes (12).

8. A method as claimed in Claim 6 wherein upon receiving its routing information, each node (12) will send a "ACK" beacon to the server (10) to acknowledge receipt of the routing information.

9. A method as claimed in Claim 6 wherein when all the nodes (12) received the routing information, the server (10) will be in the ready

state to periodically poll readings from the tracked nodes' (12) data loggers.

10. A method according to the invention as claimed in Claim 1 which
5 comprises the process in which the server (10) will re-compute optimal routing table when there are changes in the ad-hoc wireless network (16) structure and wherein the method comprises the steps of:
- 10 (a) Server will broadcast a "ALIVE" request for each node (12) to respond that it is "ALIVE".
- (b) Upon receipt of the "ALIVE" request, a node (12) will respond with an "ALIVE" beacon signal and wherein each node (12) will also relay any "ALIVE" beacon signal from
15 its dependent neighboring nodes (12).
- (c) Nodes (12) that are having problems sending "ALIVE" reply packet to its parent node (12) will indicate in their packet that there are problems sending to their parent node (12) and wherein the neighboring node(s) (12) of
20 these nodes (12) will help to relay these "ALIVE" reply messages.
- (d) The server (10) will capture and store any node's (12) "ALIVE" reply to a temporary data store.

- (e) Once there are no more new “ALIVE” replies, the server (10) will generate a list of nodes (12) that failed to respond and an alert notifications of the nodes (12) that failed to respond with “ALIVE”, excluding the nodes (12) that are manually removed by the system administrator, will be sent to the system administrator.
- (f) The server (10) will use the updated list of nodes (12) information as the input to the optimal shortest path algorithm and wherein a node (12) and network load balancing will also be applied to generate the new optimal routing path from the server to each node (12).
- (g) This updated routing table will be updated to the server (10) and the temporary storage used to capture “ALIVE” messages will be cleared.
- (h) This updated routing table will be broadcasted across the ad-hoc wireless network (16).
- (i) When a node (12) receives the updated routing information, it will capture and store the routing information that is relevant to it self and this will include its parent and assigned immediate neighboring nodes (12) and wherein a “ACK” message will be sent back to the server (10) to indicate receipt of the updated routing information.

- (j) Once all the nodes (12) receive and update their routing information, the server (10) will be in the ready state to periodically poll readings from the tracked nodes' (12) data loggers.

5

11. A method according to the invention as claimed in Claim 1, which illustrates the process in which the server (10) periodically poll readings from the tracked nodes' (12) data logger (14), and wherein the method comprises the steps of:

10

- a. The server (10) sends a "Read Value" request packet to the first node (12) of the routing path of the target node (12).

15

- b. When the first node (12) receives the "Read Value" request packet, it will check if the packet is designated to itself and if yes, it will call the data logger (14) API to get the current reading and wherein said reading will be time-stamped and sent back to the server (10) via its parent node (12).

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- c. If the "Read Value" request packet is not for itself, it will relay the message to the next node (12) specified in the routing path.

- 5
- d. Once the server (10) received the readings, it will store the values of the readings and timestamps to its data store.
 - e. In the event of time-out in receiving the targeted node's (14) respond, the ad-hoc wireless network (16) maintenance process will be activated.