Title: WIRELESS HANDHELD CONFIGURATION DEVICE FOR A SECURABLE WIRELESS SELF-ORGANIZING MESH NETWORK

Abstract: A self-organizing mesh network (10) is made up of individual devices (14A-14I) configured to use other network devices to pass data from one point to another. The network (10) also includes a secondary operating mode that accommodates handheld and other non-fixed transient network nodes. Each device (14A-14I) in the network (10) maintains a configuration link that is used to detect the presence of a handheld device (16). The handheld device (16) uses the configuration link to identify nearby network devices (14A, 14C, 14H). A user of the handheld device (16) can then select one of the network devices (14C) and establish a small point-to-point subnetwork between the handheld device (16) and the selected network device (14C).
WIRELESS HANDHELD CONFIGURATION DEVICE FOR A SECURABLE
WIRELESS SELF-ORGANIZING MESH NETWORK

BACKGROUND OF THE INVENTION

This invention relates generally to self-organizing mesh networks. In particular, the invention relates to a wireless handheld configuration device and an operating mode that allows the handheld device to communicate with a selected device of a self-organizing mesh network.

A self-organizing mesh network is a communications network made up of individual devices that are configured to use other networked devices to reliably pass data from one point to another. Ideally, each device has many paths available for passing data to its intended destination. When a new device joins the network, a network manager provides the new device with a schedule which the new device will use to talk to other devices in the network. Each device in the network is provided with "slots" (specific times and radio frequencies) for passing data to or from one or more "children" and one or more "parents". Using different times and frequencies allow many devices to pass messages in the same space without collisions. Frequency hopping also helps to secure the data that is being passed in the network. Secured self-organizing networks frequently employ authentication and encryption to further protect the network. While these attributes result in a very secure and reliable network, they also make it difficult and inefficient to use a wireless hand held configuration device in the network, because it may take several minutes for the device to be recognized in the network and to establish necessary communication links to the wireless devices to be configured. The presence of such a "transient" participant in the network can also disturb the network, making it less efficient and more power hungry as the device joins, moves around in and un-joins the network.

Secure self-organizing mesh networks of the type in question use a process known as "joining" to incorporate new devices into the secured network. During the joining process, a number of information exchanges and configurations take place.

The new device uses a network pre-determined channel to discover similar devices within radio range. These are the existing network nodes the new device has available to it in order to gain membership into the network. The presence of each device within earshot is recorded. Later in the joining process, the new device will provide its "neighbor" list to the
network manager so that the network manager can determine the links that must be established to allow the new device to participate in the network. The network manager also needs to be aware of “excess” neighbors not needed for the new device to communicate on the network. The network manager must ensure that the newly established links do not interfere with the pre-existing links of these neighbor devices.

The new device uses its pre-configured security information to decode a joining message from the manager and sends back the expected security response along with other information necessary for the manager to establish links from the new device to other devices in the network.

The new device and the new parents and children receive and implement configuration information from the network manager to establish the required links. The new device is then fully joined and participating in the network.

In most networks, the joining process described above happens only when new devices join the network. The process may take some time (15 to 20 minutes depending on the network) but since it happens very infrequently, the impact is minor. A wireless handheld device used to interrogate and configure devices in the network may, however, join many times as it is moved around to configure different devices. It is not practical for this type of device to join the network as if it were a standard fixed position device. Not only would this be extremely inconvenient for the user to wait many minutes for the handheld device to join the network, but the frequent joining and un-joining will impact network performance. There is a need for a different method for allowing special devices (such as a wireless handheld configuration device) that are not fixed in the network to join and leave a self-organizing mesh network.

**BRIEF SUMMARY OF THE INVENTION**

A self-organizing mesh network is provided with a secondary operating mode that accommodates handheld and other non-fixed transient network nodes. Each of the network devices maintains a configuration link to detect presence of a handheld device. The handheld device uses the configuration link to build a “neighbor” list of nearby network devices.

The user of the handheld device can select one of the network devices, and establish a point-to-point subnetwork over which the handheld device and the selected network device
can communicate. Once the point-to-point network is established, the handheld device and the network device can pass data securely, for example by using a pre-configured join key to encrypt data, or through an automatic exchange of a temporary configuration encryption key.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a diagram illustrating a self-organizing mesh network.

FIG. 2 shows a handheld device utilizing a secondary operating mode of the mesh network to establish contact with one of the network devices.

FIG. 3 shows the handheld device communicating with one of the network devices over a point-to-point subnetwork.

DETAILED DESCRIPTION

FIGS. 1-3 show self-organizing mesh network 10, which includes network manager 12 and individual devices or nodes 14A-14I. Self-organizing mesh network 10 is a wireless communications network in which individual devices 14A-14I pass data through multiple paths.

Network manager 12 may comprise, for example, a software application running on a network gateway or on a host computer. Network manager 12 can communicate directly with some of the devices (in this case devices 14A, 14B, 14C, and 14F) and can communicate indirectly with the remaining devices.

When each of the devices 14A-14I joined network 10, network manager 12 provided that device with a schedule to use in talking to other devices within network 10. Each device is provided with slots representing specific times and radio frequencies which they use to pass data to and from nearby devices that are either children or parents to that device.

In one embodiment, devices 14A-14I are field devices in a distributed industrial process system. The field devices may be transmitters having a sensor (or sensors) to monitor a process parameter such as pressure, temperature, flow rate, or fluid level. Alternatively, the field device may include an actuator for providing the control function in response to a signal received over network 10.

FIGS. 1-3 also show handheld wireless communicator or configuration device 16, which may be used by an engineer or technician to interrogate and configure individual devices 14A-14I in network 10. Handheld configuration device 16 is capable of wireless
communication with each of nodes 14A-14I, and may be moved so that it is near a particular
device during the interrogation or configuration process.

Handheld device 16, however, presents a problem with respect to joining and leaving
network 10. It is not practical for wireless handheld device 16 to join network 10 in the
same way as a standard fixed position device (like devices 14A-14I). The time delays
required to join network 10 and the frequent joining and leaving of network 10 by wireless
handheld device 16 would have a negative impact on performance of network 10.

In the embodiment shown in FIGS. 1 and 2, network 10 has both a primary operating
mode in which devices 14A-14I communicate with one another and network manager 12, as
well as a secondary operating mode that allows establishment of a point-to-point subnetwork
between wireless handheld device 16 and one of the devices 14A-14I of network 10. This
secondary operating mode accommodates a wireless handheld configuration device and
other handheld or non-fixed transient network nodes. Each device 14A-14I in network 10
maintains a configuration link that is used to detect presence of handheld device 16 or other
transient network nodes. The link includes a special communication slot that all devices
14A-14I share. In other words, all of the devices use the same time and the same frequency
for the special communication slot.

Handheld device 16 is programmed to listen on the special frequency in order to
establish contact with nearby devices of network 10. Handheld device 16 will listen for the
special frequency over a longer time period than the duration of the special communication
slot, because it is not initially synchronized to network 10. When handheld device 16
detects transmission from one or more of devices 14A-14I, it uses the special
communication link to build a neighbor list in a manner that is similar to that used in the
standard join process.

As shown in FIG. 2, handheld device 16 is located near nodes 14A, 14C, and 14H.
When handheld device 16 has built a neighbor list identifying devices 14A, 14C, and 14H, it
then presents a list via a display to the user of handheld device 16. The list identifies those
network devices within earshot of handheld device 16. In this particular example, the list
would include devices 14A, 14C, and 14H. The user can then select one of those devices to
establish communication.
As shown in FIG. 3, the user has selected device 14C. Using only the join key and a network ID (both of which are programmed into handheld device 16), handheld device 16 and network device 14C create a small point-to-point subnetwork. The creation of the point-to-point subnetwork is accomplished through the temporary dedication of currently unused communication slots of network 10 to create opportunities for network device 14C and handheld device 16 to communicate with one another. This point-to-point network can be established entirely without participation of network manager 12, and can be done very rapidly. Once the point-to-point network is established, handheld device 16 and network device 14C can pass data securely either by using the preconfigured join key to encrypt data, or through an automatic exchange of a temporary configuration encryption key.

Upon completion of the configuration process, handheld device 16 terminates the point-to-point subnetwork, and then can be moved to another location in order to configure another one of the devices of network 10. During the time that the point-to-point subnetwork is in existence, the primary operating mode of network 10 continues. Handheld device 16 does not fully join or participate in network 10. Rather, it communicates on an individual basis with only one of the devices of network 10, using communication slots that are not being used by any other device within network 10.

Although the present invention has been described with reference to preferred embodiments, workers skilled in the art will recognize that changes may be made in form and detail without departing from the spirit and scope of the invention.
CLAIMS:
1. A wireless self-organizing network comprising:
   a plurality of devices configured to use other devices to pass data over the network,
   each device having a common communication slot; and
   a handheld wireless communicator capable of communicating with the devices using
   the common communication slot to establish a temporary point-to-point
   subnetwork with one of the devices.
2. The network of claim 1, wherein the configuration slot is a common time and
   frequency shared by the devices for establishing communication with the handheld wireless
   communicator.
3. The network of claim 1, wherein the handheld wireless communicator builds a
   neighbor list of devices whose presence has been detected on the common communication
   slot.
4. The network of claim 3 wherein the handheld wireless communicator displays the
   neighbor list for user selection of the device with which the temporary point-to-point
   subnetwork is established.
5. The network of claim 4, wherein the handheld wireless communicator provides a
   join key and a network ID to the selected device.
6. The network of claim 1, wherein the temporary point-to-point network uses
   communication slots not currently being used for passing data among the plurality devices.
7. A wireless self-organizing mesh network of individual devices, the network
   comprising:
   a network manager for establishing a primary operating mode in which data is passed
   over the mesh network using the individual devices; and
   a configuration device capable of establishing a temporary point-to-point connection
   with a selected one of the individual devices using a secondary operating
   mode of the mesh network.
8. The mesh network of claim 7, wherein each of the individual devices includes a
   configuration slot for establishing communication with the configuration device.
9. The mesh network of claim 8, wherein the configuration slot comprises a time and
   frequency shared by the individual devices.
10. The mesh network of claim 7, wherein each individual device includes software that allows establishment of the temporary point-to-point connection between the individual device and the configuration device without participation of the network manager.

11. The mesh network of claim 7, wherein communications over the point-to-point connection between the individual device and the configuration device are secured through the use of a network encryption key.

12. A method of providing communication between fixed network nodes of a wireless mesh network and a non-fixed transient node, the method comprising:

   positioning the non-fixed transient node in a vicinity of at least one of the fixed network nodes;

   detecting at the non-fixed transient node wireless transmissions from at least one of the fixed network nodes; and

   establishing a temporary point-to-point subnetwork for communication between the non-fixed transient node and one of the fixed network nodes whose wireless transmission was detected.

13. The method of claim 12, wherein the fixed network nodes have a common communication slot for establishing communication with the non-fixed transient mode.

14. The method of claim 13 and further comprising:

   building a neighbor list of fixed network nodes whose wireless transmissions on the communication slot have been detected.

15. The method of claim 14 and further comprising:

   displaying the neighbor list.

16. The method of claim 15, wherein establishing a temporary point-to-point subnetwork is in response to a user selection of a node shown in the displayed neighbor list.

17. The method of claim 12 and further comprising:

   providing a join key and a network ID from the non-fixed transient node to a fixed network node to which the temporary point-to-point subnetwork is to be established.

18. The method of claim 17, wherein communications over the temporary point-to-point subnetwork are encrypted using the join key.
19. The method of claim 12, wherein communications over the temporary point-to-point subnetwork are secured through use of an encryption key.

20. The method of claim 12, wherein the non-fixed transient node comprises a handheld wireless configuration device, and further comprising:

configuring the one of the fixed network nodes with the handheld wireless configuration device using communications over the temporary point-to-point subnetwork.
FIG. 3