EkoTek Low Power Radio Mesh Networking

multitone
EkoTek
Echo Technology

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1/ Scope

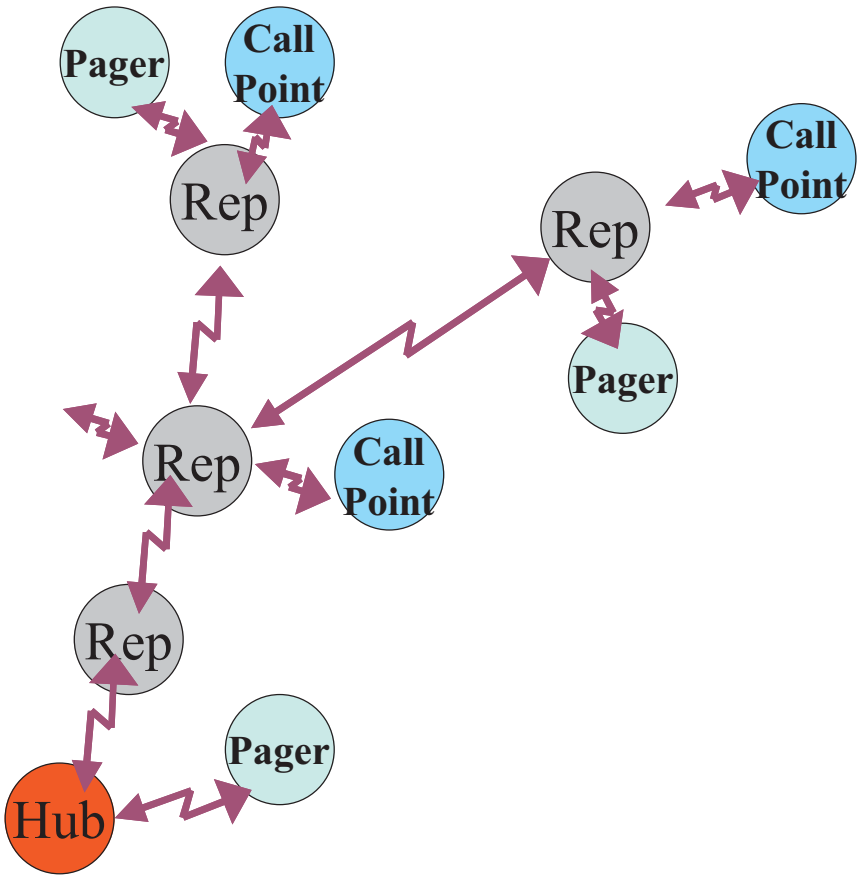
This document gives an overview of a radio mesh network and the low power technology that can be used for implementation of the network.

2/ Background

A mesh network is a type of network where co-operating nodes form connections that are used for traffic flow through the network. The term “mesh” is used as traffic may have more than one potential route through the network, providing the possibility of traffic load sharing and resilience.

The Internet is a well known mesh network, where Internet Routers form the network nodes that handle the traffic flow.

This document is specifically concerned with low power radio mesh networking and describes an implementation used by Multitone Electronics in its EkoTek range of products.



3/ Requirements

Key requirements for a low power radio mesh network are :

- Battery powered with long battery life : as multiple nodes form the mesh network, installation costs would be high if each node required a mains power supply. Battery powering allows nodes to be installed quickly and easily with a very low installation cost.
- Resilience : failure of any node should not cause the network to fail. The network should automatically route around a failed node.
- Self-configuration : the number of potential radio paths available in a radio mesh network can be considerable. This makes the network robust but means that manual configuration is not practical. The network must automatically configure routes through the network.
- Ease of expansion : changes to the network must be straightforward to implement

4/ Radio Technology

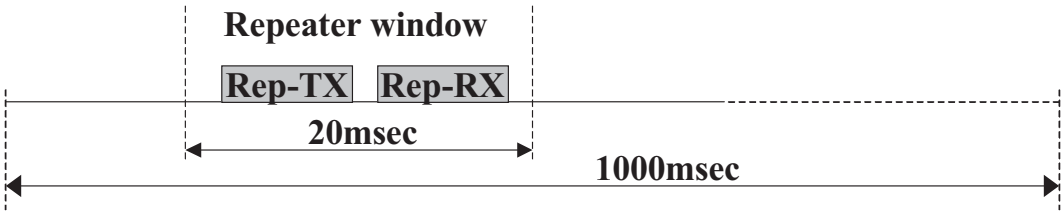
A number of radio technologies exist that could be used to create mesh networking products. For Multitone's EkoTek range of products, the requirement for battery powering with a battery life of at least 2 years meant that the latest technology low power radio devices were the appropriate solution.

The chosen radio technology is IEEE 802.15.4 which specifies a radio technique specifically aimed at battery operated devices and giving a long battery life.

5/ Meeting the Requirements

5.1/ Battery power : IEEE 802.15.4

This specification defines a radio system that may be used in various ways. In order to minimise power consumption, the ON time of the radio transmitter and receiver must be minimised. This is achieved by operating the node radio in beacon mode.

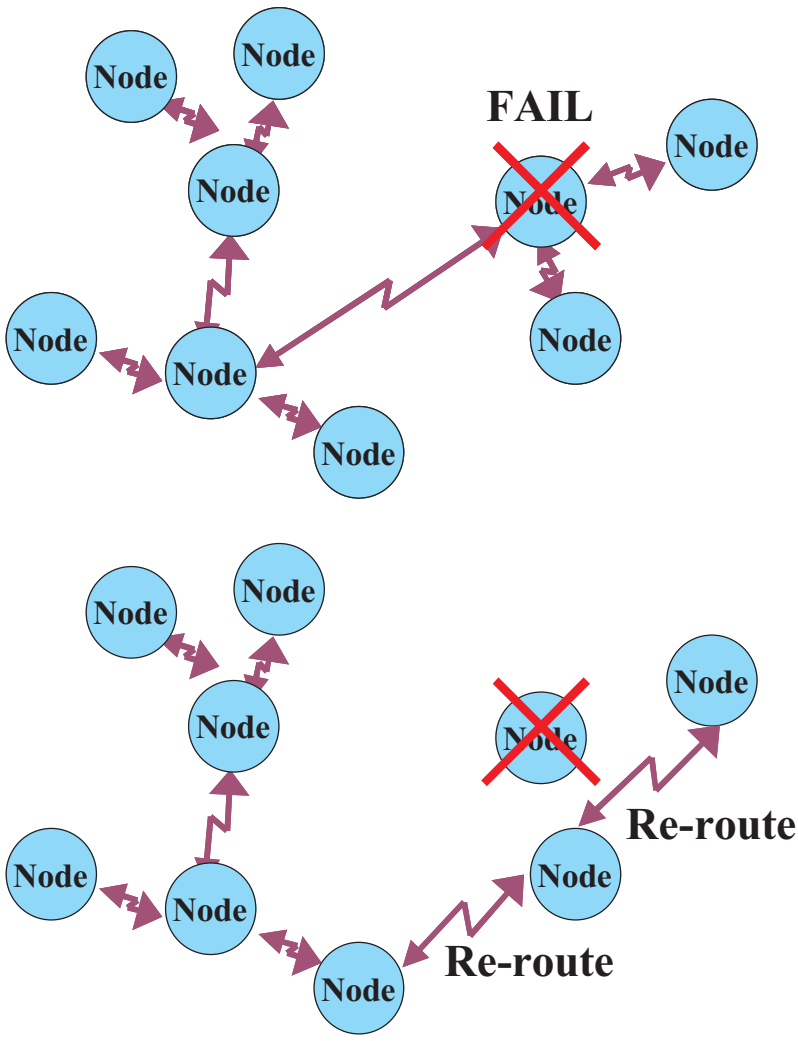


In beacon mode each node (Repeater) has a specific time window in which it transmits/receives. Outside of this window the node is inactive and therefore battery consumption is minimised. In the above example the node window lasts for 20 msec and repeats every 1000msec.

As the window is of relatively short duration, the tx/rx data rate must be relatively high to ensure that sufficient data can flow during the window period :in the case of IEEE 802.15.4 it is 250 kbit/s.

5.2/ **Resilience**

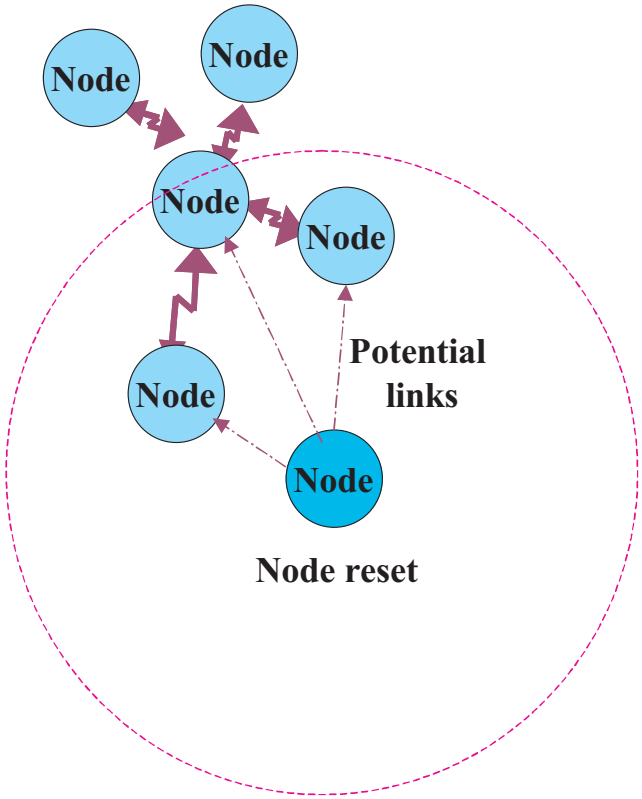
Traffic links to neighbouring nodes are continuously tested. Should a link fail, that link is dropped and the node automatically looks for a new link to another node.



5.3/ **Self-Configuration**

When a node resets or on failure of a link to an adjacent node, the node performs a radio scan and selects an adjacent node with good signal strength as a route to pass traffic via the network.

In the above example, the node that has reset has performed a scan and detected three neighbouring nodes that could potentially be used for traffic links. One of these will be selected, normally based on link testing and signal strength.



5.4/ **Ease of Expansion**

Changes to the network, normally expansion but may also involve moving part of the network, must be straightforward to implement. Traditional 1-hop radio networks suffer from the single hop radio path normally requiring multiple wired base stations to provide site coverage, making expansion costly and difficult. A mesh network is easily expanded simply by adding additional nodes (Repeaters) in the required location. In addition, as EkoTek's Repeaters are battery powered, no wires are required to be installed for expansion, making the task very quick and easy.

6/ Summary

The IEEE 802.15.4 radio network chosen for Multitone's EkoTek range of products provides the following :

- Ease and low cost of installation due to the use of battery powered nodes (Repeaters).
- Long battery life using beacon window tx/rx.
- Ease of installation as the network self-configures at startup.
- Resilience as the network automatically re-configures on node or link failure.
- Easy expansion simply by adding battery powered nodes (Repeaters) where required.

EkoTek
Personal Security & Lone Worker
System Overview

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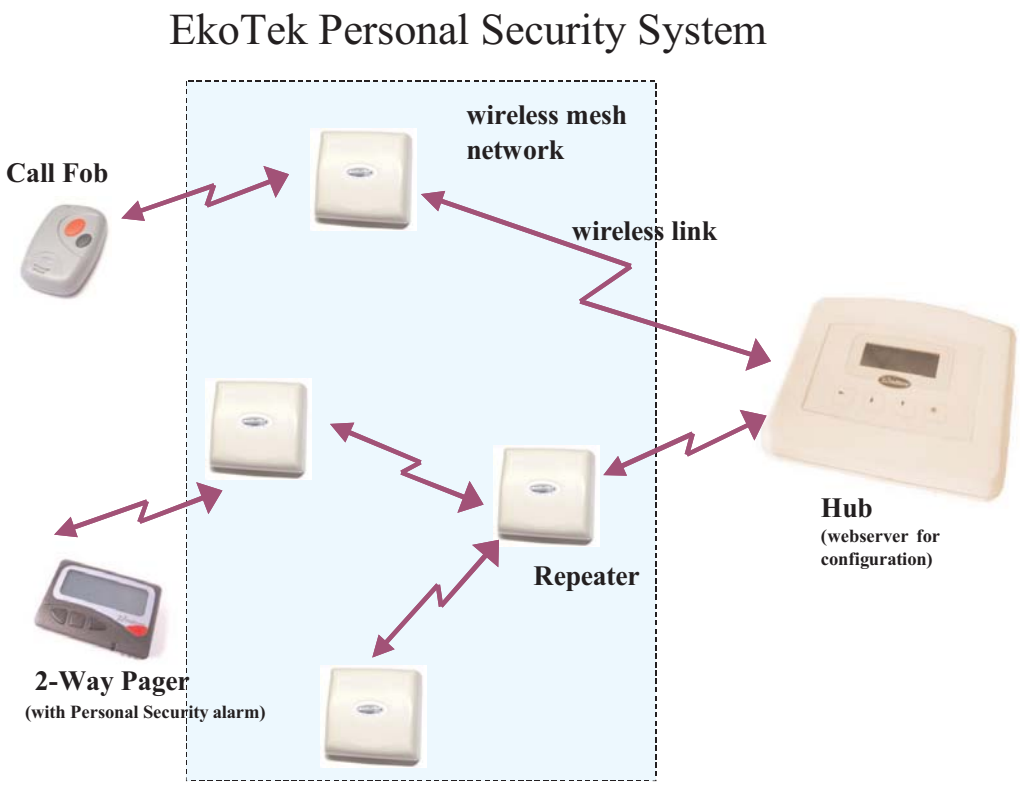
1/ Scope of Document

This documents describes applications, principles, components and operation of Multitone's EkoTek Personal Security system.

EkoTek's Personal Security / Lone Worker system allows assistance calls to be made via radio, making the product suitable not just for personal security applications but also for applications where general assistance is required, such as a resident in a nursing home calling for help with dressing or a worker in a warehouse calling for another worker to help with lifting a box.

2/ EkoTek Personal Security Lone Worker System

EkoTek's personal security system consists of mobile devices that send assistance messages to other fixed or mobile devices where the assistance message and location of the caller are displayed.



Messages are communicated via a backbone radio network that makes use of Repeaters to relay messages around the network.

Due to the multi-hop nature of the backbone network, the physical shape and size of the network is defined by the layout of the Repeaters, which may be in 3 dimensions e.g. covering multiple floors in a building.

EkoTek is truly wireless (only the Hub needs AC power), making installation and expansion very quick and easy.

3/ Applications

Due to the flexible EkoTek system , many applications are possible including:

3.1/ Building Security

EkoTek's backbone network operates in 3 dimensions, allowing coverage to extend across and between floors of a building.

Installation is quick and low cost as Repeaters are battery powered and are truly wireless.

3.2/ Hospital Security

Medical staff and other workers dealing with the public benefit from the peace of mind brought about by having a compact personal alarm unit (Call Fob) they carry. The alarm unit signals the alarm to the Hub display and also to security personnel via either EkoTek 2-way Pagers or traditional 1-way Pagers.

3.3/ Nurse Call

Patients use a Call Fob to signal for assistance, with the Fob assistance message providing the patient location in the message.

As the Call Fob is small and light, it can be worn around the neck of the patient.

3.4/ Security Guard Protection

Security guards often have to patrol areas where there is no other person nearby to provide assistance in the event of an incident.

The EkoTek system Call Fob can generate an alarm at both the central Hub, normally located in a security room, and dial across the telephone network by connecting the Hub to an autodialler to raise the alarm with off-site personnel.

3.5/ Car Park and Campus Security

Unlike other systems which utilise infra-red signals for location determination, EkoTek's radio based location determination operates indoor or outdoors, day or night. This allows EkoTek Repeaters to be mounted outdoors, typically on lamp posts, extending the EkoTek coverage across car parks and walkways, allowing virtually any shape of network coverage to be created.

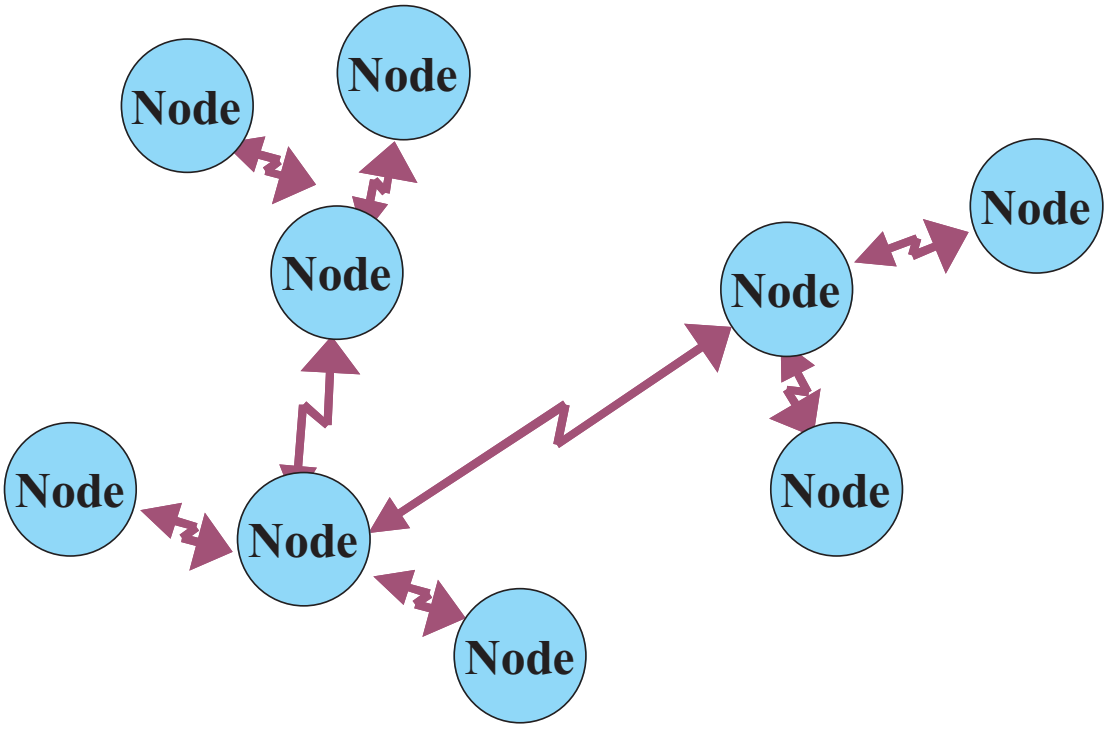
The low installation cost and long battery life of the Repeaters helps keep overall costs low.

3.6/ Co-worker Calling

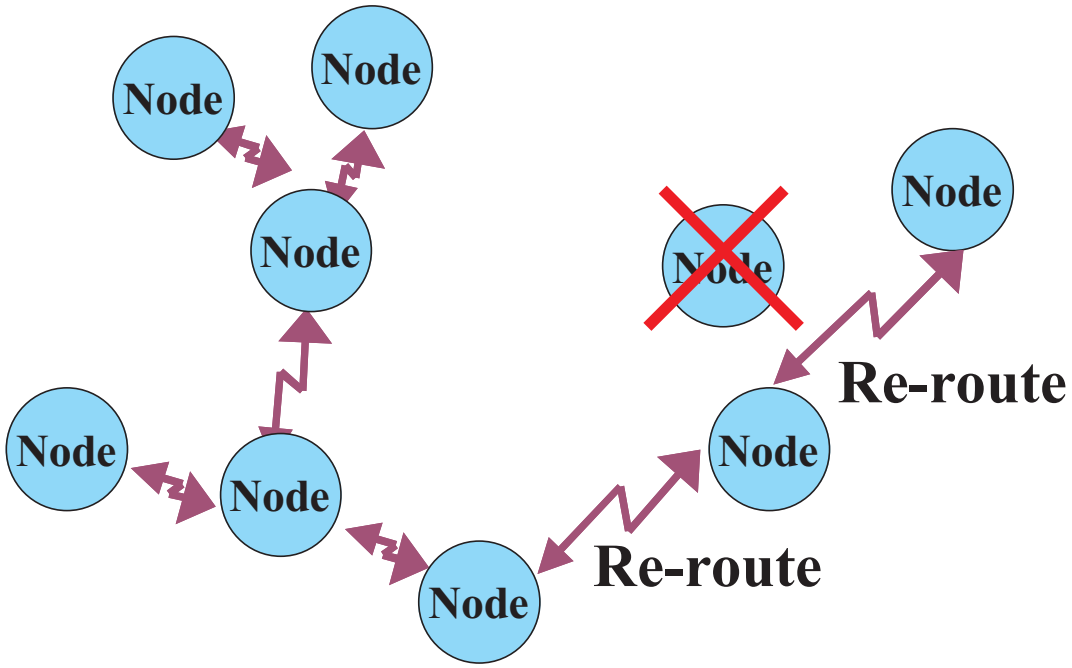
Workers who attend machinery and those who work in locations where it can be difficult to locate colleagues use EkoTek Call Fobs to contact other workers for assistance, perhaps to ask for a break from work or to help with a work task.

3.7/ 2-Way Task Management

2-way paging messages created on the Hub can be responded to by Pager users as a "Yes/No" response. This provides simple task management and the potential to create many types of message/response systems.



4/ EkoTek Principles



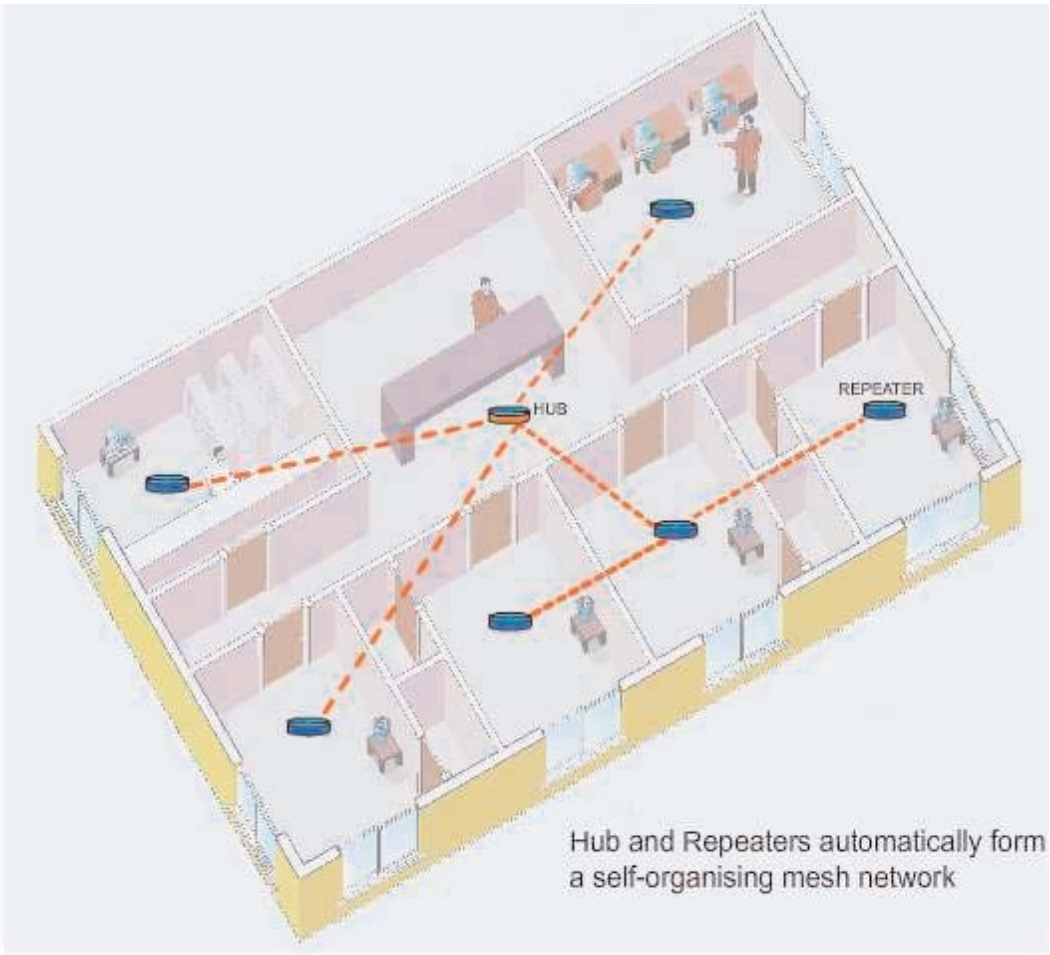
4.1/ Self-Organising Mesh Radio

Each EkoTek product is a node that forms part of a self-organising radio mesh network. Each node in the network searches for links to nearby nodes to form the network mesh. Organising the network is an automatic function carried out by the nodes themselves – configuration is not required.

As the network is self-organising it is also self-repairing. Should a node (Repeater) fail, the network will automatically re-configure around the failed node. The dimensions of the network are defined by the layout and distribution of Repeater nodes, the layout being arranged to meet the requirement e.g. reception and public areas of a hospital accident and emergency department or all floors of a building for security guard loneworker protection.

Sizeable networks can be easily built due to the large number of Repeaters supported by EkoTek.

Repeaters are normally installed on walls and/or ceilings. The Hub is installed either on a wall or on a desk so that the Hub display can be easily seen.

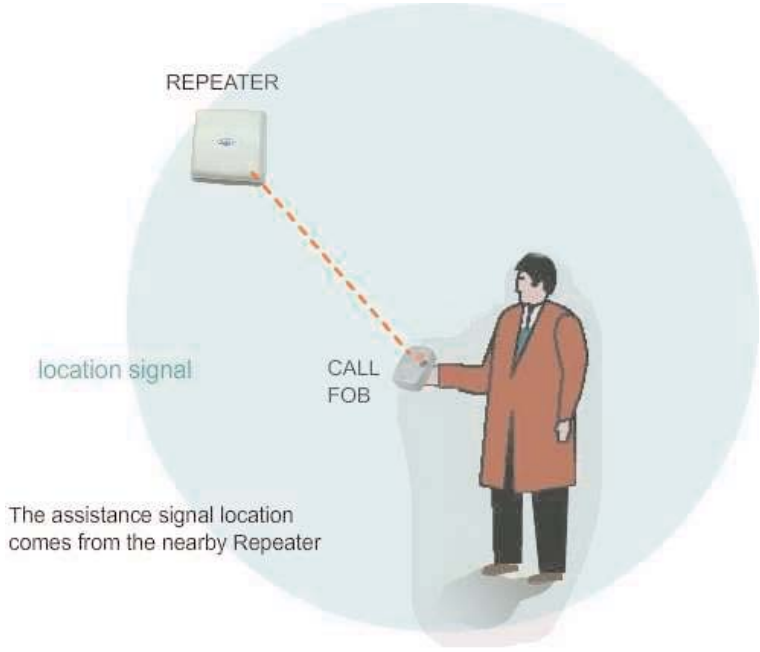


Hub and Repeaters automatically form a self-organising mesh network

4.2/ Accurate Location Reporting

When a user raises an alarm signal, it is important to know the location of the user to ensure that assistance arrives as quickly as possible.

EkoTek provides accurate location reporting based on location signals sent out by Repeaters.



When a user signals an alarm, the user identification (name), location and alarm type are included in the alarm message displayed on the Hub and sent to Pagers.

4.2.1 / 2-Way Acknowledgement

For peace of mind of the User, acceptance of the alarm at the Hub or a 2-Way Pager by someone who will be going to the aid of the user is signalled back to the user by the Call Fob lamp and beeper changing their alert patterns.

4.3/ 2-Way Radio

All EkoTek radio links are 2-way, providing the ability to signal both to and from all devices on the network. 2-way radio provides the ability to quickly detect and correct any lost messages e.g. when a message is relayed from one Repeater to a second Repeater, the second Repeater will acknowledge receipt of the message.

If the first Repeater does not receive an acknowledgement, it retransmits the message. This ability allows EkoTek to function even in environments where there is radio interference or poor signal.

A further benefit of 2-way radio is the ability to download configuration to all devices from the Hub using over air programming: devices do not hold their own configuration as this is sent by the Hub on request when devices are powered up. Hence even Pagers have their configuration held at the Hub, making it unnecessary to recall mobile devices for configuration change as updates are made at the Hub.

4.3.1/ Frequency Hopping

EkoTek radio links can be configured to operate on a fixed frequency or to hop across all 16 available frequencies. Frequency hopping increases the immunity of EkoTek systems to radio interference : if a message is lost due to interference on a frequency, the loss is immediately detected and the message retransmitted on the next frequency in the hopping sequence.

Frequency hopping is especially useful where the local radio environment may be unknown or subject to change : EkoTek's combination of message loss detection, automatic message retransmission and frequency hopping makes for a very robust radio infrastructure.

5/ Components

5.1/ Single Hub

The Hub forms the central device in the mesh network. All communications pass to and from the Hub, which can be located at any physical point on the network i.e. it can be at the edge of the network as it does not need to be at the physical centre.

A Hub display shows alarm messages in a similar way to a 2-Way Pager.

For configuration, a PC running a web browser is connected via ethernet to the webserver running on the Hub.

Other connections on the Hub are for an alarm relay, external paging systems and power.

Internal rechargeable batteries allow the Hub to function for several hours should the AC power fail.

5.2/ Call Fob

The Call Fob allows assistance calls to be raised, using the location signals from Repeaters for accurate location determining.

Dead-man and man-down features are supported by the Call Fob. Configuration of the Call Fob is downloaded from the Hub when the Call Fob is powered up.

Enabling of Call Fob features is by Hub configuration. All Call Fobs are physically identical and support the same features (if enabled at the Hub).

An LED, buzzer and vibrate motor are contained within the Call Fob and are used to indicate the call status, changing when a call is accepted by a remote user on the Hub or a 2-Way Pager. Indication of assistance on its way is signalled in this way.

An AAA battery powers the Call Fob. Either rechargeable NiMh or disposable alkaline batteries may be used.

5.3/ Repeater

Repeaters form the backbone of the self-organising radio mesh network. Each Repeater automatically forms links to nearby Repeaters to allow messages to pass across the backbone.

Two screws hold the Repeater on a ceiling or a wall. Two internal alkaline D cell batteries power the Repeater, the voltage of which is monitored and reported to the Hub and/or Pagers should the voltage fall, requiring that the Repeater batteries be replaced.

Repeaters also transmit location beacon signals, which are used by mobile devices to determine location, which is sent when assistance messages are generated.

Repeaters form the mesh network in 3 dimensions, with Repeater-Repeater radio links passing via walls and ceilings if necessary.

All Repeaters operate on the same radio channel as the Hub by default. This is the configuration used by most systems and it is not normally necessary to change the configuration from the default. However, where there is a need to force Repeaters to make links to other specific Repeaters e.g. when a building-building link is required and this is specifically designed to be above the height of passing vehicles, Repeaters can be configured at the Hub to only operate on specific channels.

See the Multitone document “Example EkoTek System Configurations” for more information on ‘special’ configuration.

Battery replacement is quickly achieved by sliding the Repeater from the backing plate and lifting out the old batteries. No tools are required for this. An optional locking screw can be inserted where necessary to help prevent tampering with the Repeater e.g. where the Repeater is installed in a public environment within reach of passers by.

Repeaters continually test links to adjacent Repeaters, detecting link failure and automatically searching for and establishing a new link should a link fail.

Network moves and/or expansion is achieved by moving or adding new Repeaters where required, making network changes rapid and cost effective.

5.4/ Call Point / Repeater

The Call Point / Repeater provides the same functions as a Repeater together with the additional function of a button for assistance calls.

When a Call Point is installed within a room it is not necessary to install a separate Repeater in the room as the Call Point forms the radio backbone network in the same way as a Repeater.

5.5/ 2-Way Pager

EkoTek's 2-Way Pagers have the following key functions:

- Display of and response to assistance calls from other 2-way devices
- Display of paging messages created by using the Hub webserver
- Display of paging messages coming from an external system via the Hub serial input
- Generation of personal security assistance calls (same as a Call Fob)

5.5.1/ Display of and Response to Assistance Calls

EkoTek's 2-way radio network provides message interchange between devices. For example, when a Call Fob raises an assistance message, this is displayed on Pagers and the Hub.

A Pager/Hub user can then accept the call, which is then signalled back to the Call Fob and indicated, to the user by a change in the LED/beep pattern being emitted by the Call Fob during the assistance call.

5.5.2/ Display of Web server Paging Messages

A 2-Way paging application runs on the Hub with paging messages being created via a page on the Web server using an attached PC and web browser such as Internet Explorer.

The web server paging display shows when paging messages have been delivered to the Pager and also the response "Yes/No" that the Pager user is able to send in response to the message by pressing the appropriate button on the Pager.

With this 2-way paging function, simple task management systems can be easily created

5.5.3/ Paging from External System

A serial paging interface on the Hub provides the ability to connect an external system to the Hub and send messages to 2-way pagers that have come from the external system e.g. from a nursecall system.

5.5.4/ Personal Security Calls

In a similar way Call Fobs, Pagers are able to generate assistance calls using the red assistance button on the Pager or the in-built man-down or dead-man functions. A Pager can therefore function as both an alarm unit and a display, eliminating the need for certain users to carry both types of units as necessary with other systems.

5.5.5/ Powering

An AAA battery powers the Pager. Either rechargeable NiMh or disposable alkaline batteries may be used. Charging contacts on the Pager are used when the Pager is inserted into a charging rack for rechargeable battery charging.

5.6/ Configuration

Configuration for all devices is held on the Hub and downloaded to each device at power-up.

The Hub defaults allow a new system to operate ‘out-of-the-box’, only requiring the location names for the Repeaters to be entered on the Hub webserver configuration page.

Each device has its own unique factory set serial number for identification. There is no factory programming of devices, allowing stocking of devices as special variants are not required – the Hub configuration for devices defines whether device options (e.g. man-down) are enabled or not.

Pager addressing is configured at the Hub – there is no need to factory program Pagers.

5.6.1/ Network Parameters

An EkoTek system controlled by a single Hub is able to support up to 500 devices. See section 7 for maximum numbers for each type of device.

The default configuration is for all EkoTek devices to to use the frequency hopping radio channel used by the Hub, which defaults to channel 16. Other channels can be configured using the Hub web server interface, with up to 16 channels being used simultaneously by a single EkoTek system and Hub. See the Multitone document “Example EkoTek System Configurations” for more information on ‘special’ configuration.

A single EkoTek radio channel supports up to 94 Repeaters. The Repeaters can be deployed in any physical deployment as long as each Repeater is able to establish and maintain a suitably strong signal with a nearby Repeater that has a path back to the Hub.

Repeaters can be deployed in long chain configurations if required e.g. to extend service along a corridor.

6/ Diagnostics and Statistics

Each EkoTek device collects statistics on network performance and on messages. These statistics are regularly sent to the Hub and can be viewed using the webserver.

Failure (loss) and battery low indications for EkoTek devices are detected by the Hub and reported on the Hub and/or Pager displays.

7/ Specifications

Radio Frequency	2405 – 2480 MHz
Radio Channels	16
Channel Operating Mode	Fixed frequency or frequency hopping
Radio channels simultaneously used per system	Max 16
Radio Power	10mW
Radio Coding	CDMA IEEE 802.15.4
Hub Power	AC-DC Power Adaptor
Repeater Power	2 x D cell High Capacity Alkaline Manganese batteries
Pager Power	1 x AAA cell High Capacity Alkaline Manganese or NiMh rechargeable battery
Call Fob Power	1 x AAA cell High Capacity Alkaline Manganese or NiMh rechargeable battery
Number of Repeaters per radio channels	Max 94
Total number of Repeaters across all radio channels	Max 300
Total number of Pagers	Max 100
Number of Pagers called per message	Max 35
Total number of Call Fobs	Max 200
Total number of devices per system	Max 500