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Topology Requirements

Product Innovation

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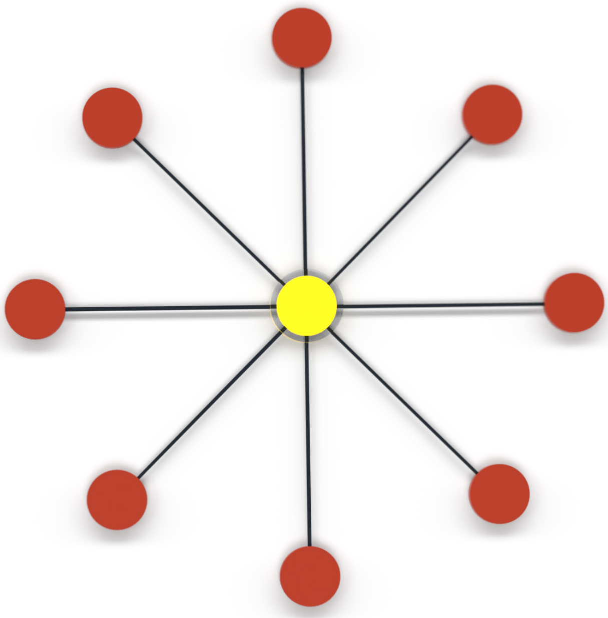
WES Radio Protocol Knowledge Article

There are a number of recognised radio network topologies each having strengths and weaknesses.

Point-to-Point Topology

Point-to-point topologies are typically used to connect two systems together over a wide area network (WAN). You can use a point-to-point connection to get data from your local system to a remote system or to get data from a local network to a remote network.

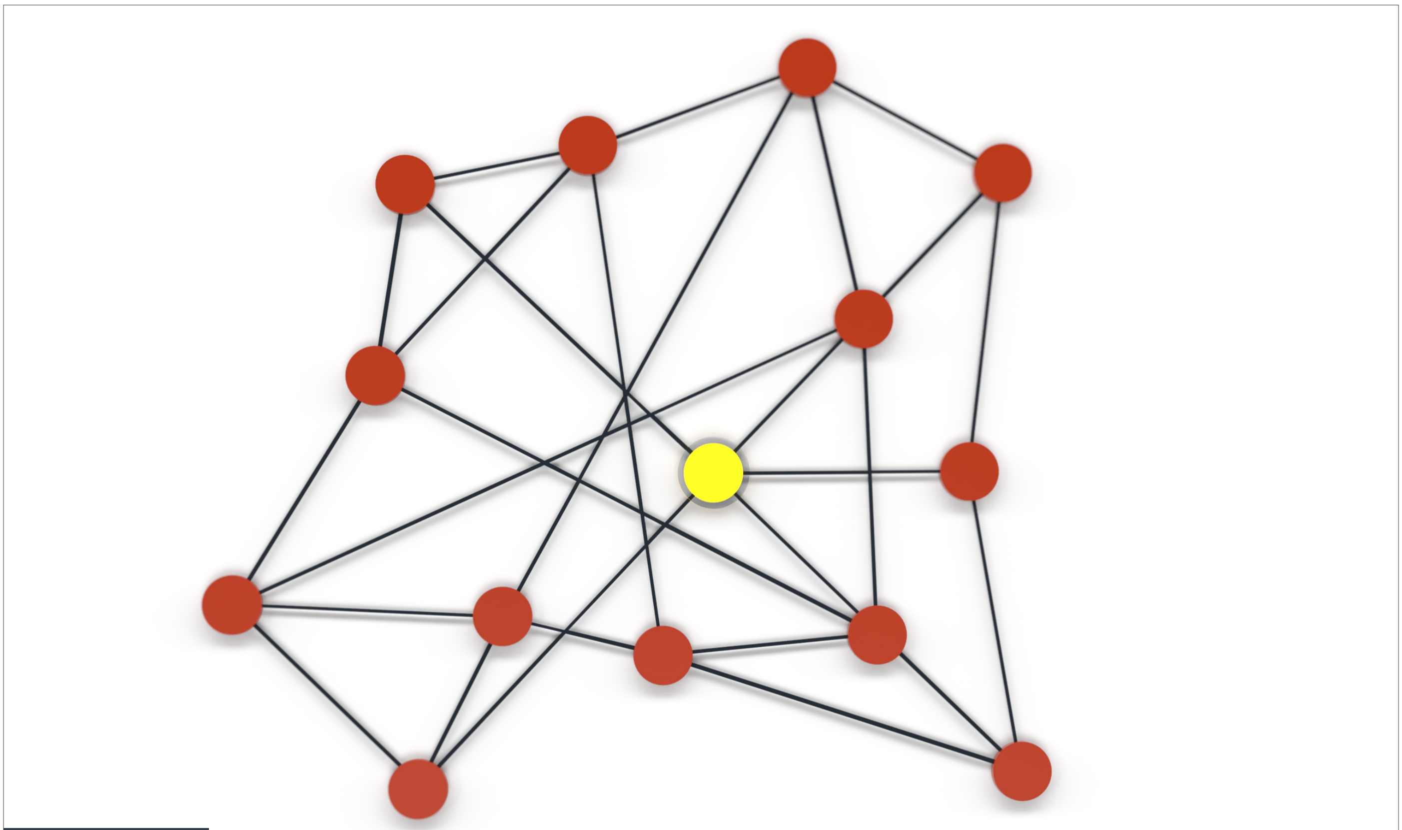
- These are extremely useful to send data over the air over longer distances.
- However, a point to point network can be susceptible to communications loss as each of the nodes in the network is potentially a single-point-of-failure. i.e. loss of one node can prevent all other nodes deployed on either side to lose communications. Due to each node having to send and receive the data these can also suffer from delays in message delivery.



Star Topology

Star Topology is typically used when there is a single gateway that controls a number of nodes in the network. This topology is used in typical office Wi-Fi networks (gateway being the router) and also in LoRaWAN networks. A Star Topology has a number of pro's and con's:

- Reliability – if one node fails all the others will still work.
- It is high-performing as no data collisions occur.
- If the gateway goes down everything goes down, none of the nodes can work without the gateway.
- Gateway requires more resource and regular maintenance because it's the central device in a star.
- All nodes must be able to communicate with the gateway directly which provides significant limitations in a challenging and dynamic communications environment.



Mesh Topology

Mesh Topology is a type of network topology in which all devices in the network are interconnected. In a mesh topology, data can be transmitted by routing (sent the shortest distance) and flooding (sent to all devices).

The two types of mesh topology are:

- Full mesh topology. Every device in the network is connected to all other devices in the network.
- Partial mesh topology. Only some of the devices in the network are connected to multiple other devices in the network.

Mesh Networks have a number of pro's and con's:

- Multiple devices can transmit data at the same time, allowing for high amounts of traffic.
- If one device fails, data transmission is not impacted in the rest of the network.
- Adding devices to the network does not disrupt data transmission.
- Network installation and maintenance is time and resource intensive.
- High power requirement due to all the devices needing to remain active all the time.

WES Network Protocol

Ramtech WES System uses a Flooded Mesh protocol to communicate from device to device as this is the most applicable to Construction sites where the environment is extremely dynamic (devices being added/removed/moved and physical environment constantly changing as the build progresses).

The WES protocol involves the originator of a message (SD/HD/MCP) transmitting a packet to air, then every WES unit that receives the message re-transmits it, and so on. This can be visualised as a wave of water spreading through the system of WES units.

Single Channel System

WES is a single channel system, so it tunes to one channel and sits listening to that channel for a message. The same channel is used to re-transmit the message, hence every WES in the system is continually listening on the same channel. This can be set per site installation and should be chosen carefully to be a quiet channel not used by anything else. Interference can affect the battery life of a system and also affect its performance.

Low Power Listening

In order that a WES unit can receive a message from another WES unit it has to be almost permanently listening. Each unit is not synchronised to any other, so a unit wakes up and listens on a short cycle and sleeps for the rest of the time (to save battery). When a WES unit transmits it needs to transmit a message for a long enough time that other WES units that are in the sleep/listen cycle will always receive it, e.g. if the unit's listening cycle is:

Because listening for a radio signal consumes significant battery power we try and minimise the listening time (since it happens constantly so that we never miss an alarm) and put the burden of power consumption onto the transmitting unit because this happens very rarely. Hence we can afford for a transmitting unit to transmit for 1 second while the other units sleep for 90% of the time (90mS sleeping, 10mS listening).

Noise Floor Monitoring

In order for each unit to remain sleeping as much as possible it must only wake when it hears a valid signal on the channel. So that a unit is quick to respond it wakes up if it hears a strong enough signal on the channel. WES is a one-channel system so we only use one channel.

Each unit continually monitors the noise floor (the background RF level on the channel) and sets a threshold a few dB above this. So if a signal is heard that's a little louder than the background noise on the channel then the unit wakes up to listen and to determine iof it's a valid WES message, if it is then it stays awake and processes the message, if it isn't (maybe interference, maybe a message on that channel from another system) then it goes back to sleep.

Receive and Re-Transmit

Every unit that hears a message will re-transmit it, hence it travels through the mesh. A message has a certain lifetime, and when a unit receives it it will pass it on and decrement the counter. Hence the message will travel through the mesh but a single unit will only transmit the same message so many times, hence eventually the message will travel through the entire mesh but will die out and the system will go quiet (otherwise it would never end as the message would continue "bouncing" through the system).

Deploying a Network

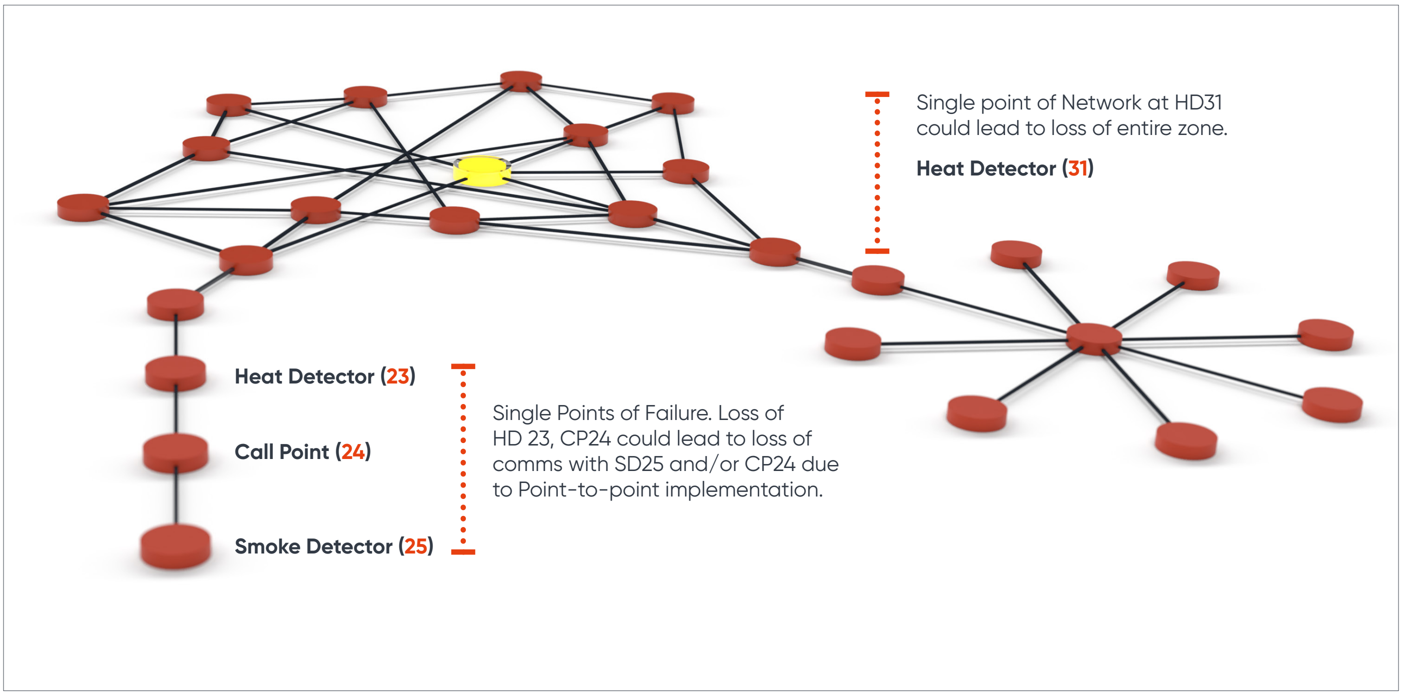
Each WES unit has a range of approximately 300 meters line of sight with no obstacles in the way. This range is much less with obstacles in the way such as brick or concrete walls, trees, steelwork, buildings.

Each WES unit should be positioned so that it can reliably hear at least two others along different paths to maximise the reliability and avoid single-points-of-failure.

If a signal cannot easily get directly from one unit to another then at least it can travel along a different path via another unit to get to the obstructed unit, this is the power of a mesh - it can be used to get around obstacles.

A flooded mesh relies on each node being able to send and receive packets from more than one other node therefore implementing a WES network in a Linear topology or forming "islands" where Links are used to connect in effect 2 mesh networks is deemed bad practice and should be avoided.

Extended Point-to-point networks are also prone to failure, WES has been tested to 32 hops maximum therefore a linear installation with numerous units deployed due to an extremely harsh RF environment is outside of the design scope of the system.



Radio path loss basics

The signal path loss is essentially the reduction in power density of a radio signal as it moves through the environment in which it is travelling. This affects all radio communication, broadcast and wireless communication systems.

There are many reasons for the radio path loss that may occur:

- Free space loss: The free space loss occurs as the signal travels through space without any other effects attenuating the signal it will still diminish as it spreads out. This can be thought of as the radio communications signal spreading out as an ever increasing sphere.
- Diffraction: Radio signal path loss due to diffraction occurs when an object appears in the path. The signal can diffract around the object, but losses occur. The loss is higher the more rounded the object. Radio signals tend to diffract better around sharp edges.
- Multipath: In a real terrestrial environment, signals will be reflected and they will reach the receiver via a number of different paths. These signals may add or subtract from each other depending upon the relative phases of the signals. If the receiver is moved the scenario will change and the overall received signal will be found vary with position.
- Absorption losses: Absorption losses occur if the radio signal passes into a medium which is not totally transparent to radio signals. There are many reasons for this which include:
    - Buildings, walls, etc: When radio signals pass through dense materials such was walls, buildings or even furniture within a building, they suffer attenuation. Vegetation: In dense forest it is found that signals even at lower frequencies are considerably reduced. This illustrates that vegetation can introduce considerable levels of radio path loss. Trees and foliage can attenuate radio signals, particularly when wet.
    - Terrain: The terrain over which signals travel will have a significant effect on the signal. Obviously hills which obstruct the path will considerably attenuate the signal, often making reception impossible.

When operating a WES network the above considerations should be made when deploying units. There is a requirement to deploy Smoke and Heat Detectors in specific areas in line with Fire Safety requirements but this may not always support radio best practice and additional units may be required. Consideration should be made on how the physical environment may compromise the networks performance.

Operating in dynamic environments can be a challenge as changes to constructions sites will alter radio paths and therefore, connectivity. It is essential that, where these conditions exist, the system is tested frequently to ensure network integrity is maintained and no units have been lost from the RF network that compromise site safety.

Radio path loss basics

Electromagnetic interference (EMI) is unwanted noise or interference in an electrical path or circuit caused by an outside source. EMI can cause electronics to operate poorly, malfunction or stop working completely.

What causes electromagnetic interference?

EMI occurs because of the close relationship between electricity and magnetism. All electrical flow produces a small magnetic field. Conversely, a moving magnetic field produces an electrical current. These principals allow electric motors and generators to work. Additionally, all electrical conductors can operate as radio antennas. High powered electrical and radio sources can produce unwanted effects in devices far away.

- Radiated EMI happens when a high-power transmitter or electrical device produces a radio frequency that is picked up and causes unwanted effects in another device. An example of this would be a an old wireless telephone causing Wi-Fi to drop.

Radiated EMI can be subdivided into narrowband and broadband interference.

- Narrowband EMI only affects a specific radio frequency and is commonly from a radio transmitter.
- Broadband EMI affects a large portion of the radio spectrum at many frequencies and is commonly caused by malfunctioning equipment.

How to prevent EMI in a WES network

The best way to prevent EMI is to position a WES unit away from potential sources of EMI such as, high voltage cables, motors, other radio devices and high powered magnets. Initial site testing may be successful but long-term degradation of devices (such as frequency drift on RF modules) is possible so affects are not always apparent immediately.