MANET and other MESH topologies

using the **Spirent Vertex RF Channel Emulator** with its **MESH software** option

Mobile Ad-hoc Networks (MANET)

Executive Summary

On a battlefield, there is no fixed communications network infrastructure. Soldiers and their equipment are mobile. Even if they do not have a connection back to Command & Control (C2) they still have a need for voice, data, and video communications with each other. Real-time, reliable, and secure communications on the battlefield is critical for a successful mission.

This is where Ad-hoc Networks, specifically Mobile Ad-hoc Networks (MANET), play a vital role for maintaining battlefield communications and situational awareness.

Real-world applications for MANET are not limited to military use cases. Vehicular fleet communications, disaster relief, and delay-tolerant networking all benefit from MANET. With the advent of newer technologies, MANET is becoming an integral part of next-generation networks because of its flexibility, the lack of requiring an infrastructure, autoconfiguration capability, less maintenance, self-administration capabilities, and cost-effectiveness.

Types of networks

Commercial	Military
• Racked hardware	• Ruggedized hardware
• Large, heavy, and power-hungry hardware	• Size, Weight, and Power (SWaP) is optimized
• Central control, hub-and-spoke	• No central control, peer-to-peer (P2P)
• Routing seldom changes, fixed	• Routing often changes, mobile

Ad-hoc networks

The term ‘ad-hoc’ is a Latin word that means "for this" implying improvised or impromptu, so an accurate descriptive for how this type of network operates. An ad-hoc network is one which is spontaneously formed so that user devices connect and communicate with each other directly with **no central control** required. Whereas central control is required by commercial networks like 5G, 4G-LTE, and Wi-Fi to operate.

In commercial networks these central controls, **Base stations** (gNB for 5G / eNB for 4G-LTE) provide for over-the-air (OTA) cellular communications and **WLAN Controllers** (WLC) providing for Wi-Fi, act as the network’s **hub** (router) through which all network traffic must flow.

In ad-hoc networks the user device for communications (Warfighter, Humvee, UAV, or Ship) acts as both a radio and router which allows for **peer-to-peer** (P2P) communications. Yes, one or more of these ad-hoc nodes must be in communication with Command and Control (C2) for command decisions, but other nodes can be outside the proximity of C2 while still maintaining communications with C2 from their peers.

Critical for military usage of networks is **mobility**, hence **MANET** (Mobile Ad-hoc Network).

MANET

MANET enables our military to use advanced RF waveform technology to operate under the most challenging conditions (i.e.: heavy interference, jamming, and non-line-of-sight (NLOS) environments) all while operating with mobility. (Land, Air, Sea and Space)

Key Difference between MANET and other MESH networks

MANET relies solely on **wireless nodes** whereas **MESH networks** are comprised of both **wireless nodes** + **fixed nodes**. So, by definition a MANET network can be classified as a type of MESH network; however, the reverse may not necessarily hold true.

Types of Ad-hoc networks

NAME	NETWORK TYPE	NODE TYPE	NODE DENSITY	NODE MOBILITY
MANET	Mobile Ad-hoc	Radio, Cellphone, Laptop	Moderate	Slow
FANET	Flying Ad-hoc	UAV, Aircraft, Helicopter	Very High	Very Fast
VANET	Vehicular Ad-hoc	Armored Vehicles, Cars, Trucks	High	Fast
SANET	Sea Ad-hoc	Ships, Boats, Submarines	Moderate	Medium

Multihop

Multihop networks, compared with networks relying on single hop, can extend the coverage of a network and increase connectivity. The typical coverage of a single hop transmitter is around 5-10km. In battlefield situations our warfighters can be separated by many times this distance. Additionally, our warfighters rely on **mobility** to quickly react to battlefield situations.

Commercial networks benefit from multihop technology by introducing router stations which are less expensive than a full base station to set up. However, this may not be an option on the battlefield where every piece of infrastructure becomes a target for the enemy. MANET radios address this by having the ability to act as a router. By being a part of the Warfighter, Humvee, UAV, or Ship there is no fixed infrastructure, as all these nodes can move.

Military usage of multihop is heavily dependent on mobility, as MANET nodes tend to be always moving. Hence it is critical that your **RF Channel Emulator** can manage for mobility.

- **Our RF Channel Emulator has Channel Bandwidth starting at 40MHz scalable to 1.20GHz**

Mobility

Doppler effect – is a physical phenomenon that is observed whenever the source of **sound waves** is moving with respect to an observer. For example: most of have experienced this doppler effect when an ambulance crosses our path with its siren blaring. From a distance the siren sounds faint; however, as the ambulance travels closer the siren sounds louder and more frequent. The ambulance has not increased the volume of the siren, instead this is occurring because its sound waves are reaching you more often, due to the ambulance proximity to you.

This phenomenon occurs with radio communications as well. Our warfighter walking about moves much slower than a Humvee, UAV, or Ship. Your **RF Channel Emulator** must provide for this doppler effect (also known as Doppler Shift).

Our RF Channel Emulator has three options for Doppler Shift:
± 4kHz for Warfighter Use Cases (terrestrial MANET radios)
± 12kHz for Humvee, UAV, or Ship Use Cases (terrestrial MANET radios)
± 2MHz for SATCOM (non-terrestrial) Use Cases [*see Dualos SATCOM whitepaper*]

- Doppler Resolution: 0.01Hz

Delay effect – is another physical phenomenon that relates to the distance between the source and the observer. Despite travelling at the speed-of-light, the further apart the transmitter and receiver are from one another, the more impactful the delay effects.

Our RF Channel Emulator has two options for Delay:
up to **± 4msec** for all terrestrial MANET radios
up to **± 2sec** for SATCOM (non-terrestrial) Use Cases [*see Dualos SATCOM whitepaper*]

- Delay Resolution: 0.1nsec

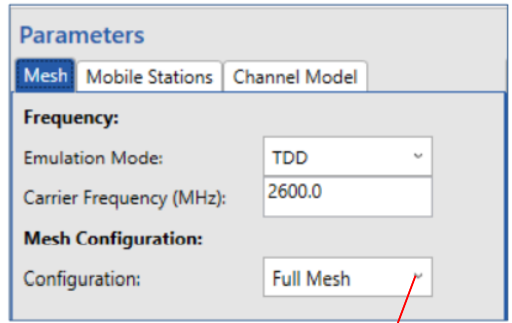
MANET Radio support from HF-, VHF-, UHF-bands in a single instrument

Vertex can be configured to test one Radio or up to 16 Radios with a single instrument. It enables you to bring the Radio's environment into the lab for controllable / repeatable measurements. It can emulate the propagation and interferences experienced by Radios when operated in the field. It can introduce doppler and delay effects to mimic terrestrial mobility. Use the Vertex's available 200MHz, or increase its Channel BW beyond, for wideband Multihop.

Concatenate Vertex units for larger Radio topologies

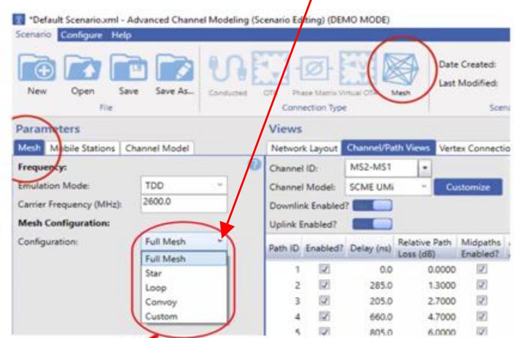
Vertex is frequency standard and waveform agnostic, enabling it to operate with any proprietary network

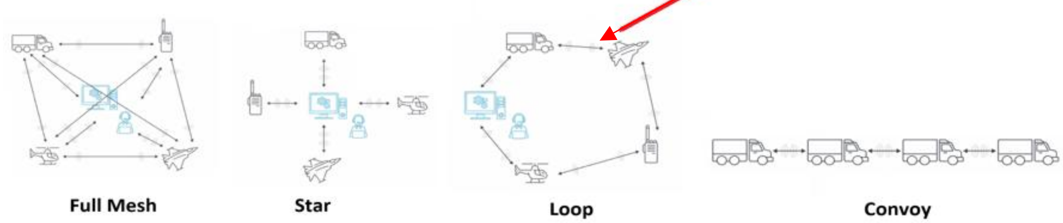
MESH – tab



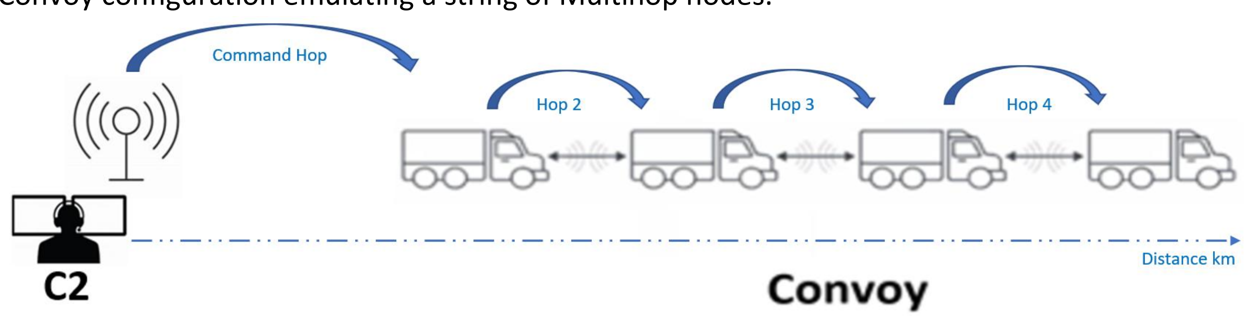
- Frequency:
  - Emulation Mode:
  - Carrier Frequency (MHz):
- MESH Configuration:
  - Full MESH
  - Star
  - Loop
  - Convoy
  - Custom
    Note: Custom is not selectable; it appears when you create a configuration that is something other than those listed.

1) Click MESH icon from toolbar
2) Click MESH tab – enter parameters
3) Click Configuration dropdown
select: Full MESH, Star, Loop, Convoy
or build Custom



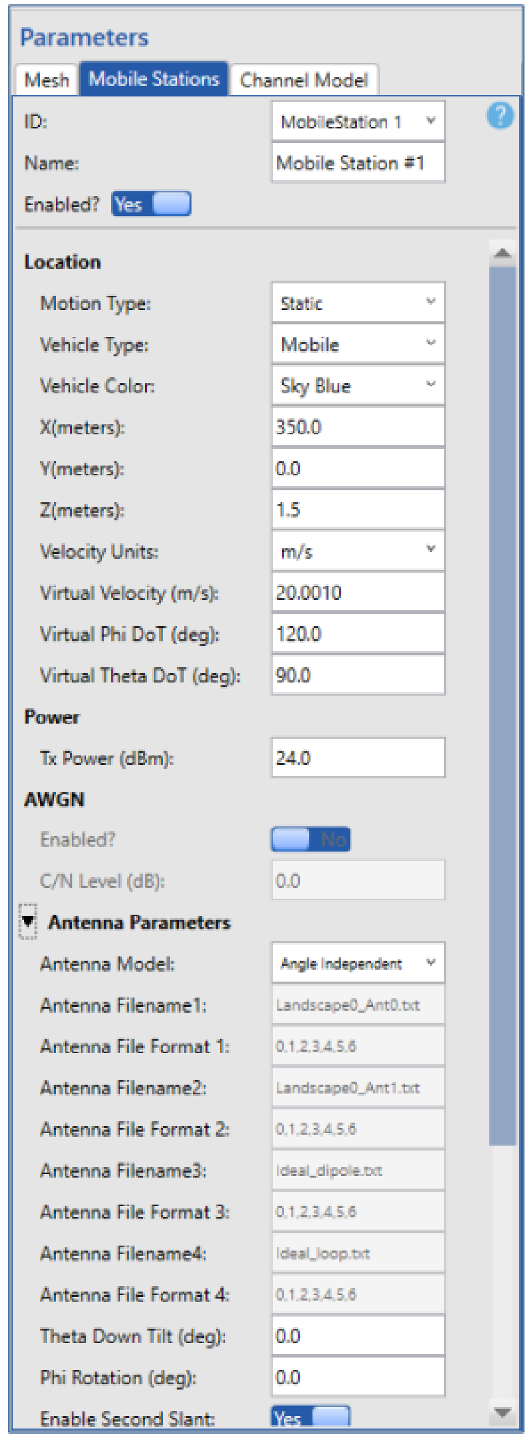


- MESH network scenarios only contain mobile stations.
- MESH network scenarios can support up to 16 mobile stations.
- All links between nodes and mobile stations are bidirectional.
- Convoy configuration emulating a string of Multihop nodes.



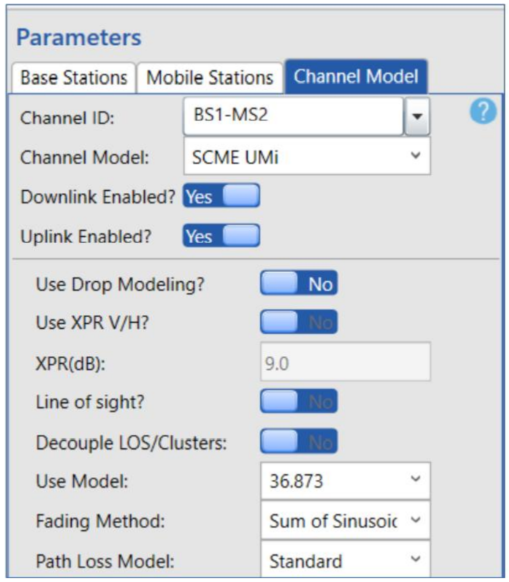
Mobile Stations – tab

- ID
- Name
- Enabled?
- Location
    - Motion Type
    - Vehicle Type
    - Vehicle Color
    - X(meters)
    - Y(meters)
    - Z(meters)
    - Velocity Units
    - Virtual Velocity
    - Virtual Phi DoT (degrees º)
    - Virtual Theta DoT (degrees º)
- Power
    - Tx Power (dBm)
- AWGN
    - Enabled?
    - C/N Level (dB)
- Antenna Parameters
    - Antenna Model
    - Antenna Filename1
    - Antenna File Format1
    - Antenna Filename2
    - Antenna File Format2
    - Antenna Filename3
    - Antenna File Format3
    - Antenna Filename4
    - Antenna File Format4
    - Theta Down Tile (degrees º)
    - Phi Rotation (degrees º)
    - Enable Second Slant?



Channel Model – tab

- Channel ID
- Channel Model
- Downlink Enabled?
- Uplink Enabled?
- Use Drop Modeling?
- Use XPR V/H?
- XPR (dB)
- Line of Sight?
- Decouple LOS/Clusters?
- Use Model
- Fading Method
- Path Loss Model



MESH – Parameters and Settings

MESH – tab

- Emulation Mode:
  Select the frequency mode you want to use. Choices are FDD and TDD
- Carrier Frequency MHz:
  Specify the carrier frequency you want to use. Range is 30.0 to 5925.0
  Note: for HF-band you will require the add on HF Upconverters to operate from 3MHz
- MESH Configuration:
  Select from Full MESH, Star, Loop, Convoy, or Custom

Mobile Stations – tab

- ID
- Name
  You can customize this label consisting of 25 characters.
- Enabled?
  Allows you to enable or disable the Location, Power, and Antenna Parameters for each Mobile Station. Choices are Yes and No
- Location
  - Motion Type
  - Vehicle Type
  - Vehicle Color
  - X(meters)
    This parameter is used when Motion Type is set to Static. Range is -10000 to 10000
  - Y(meters)
    This parameter is used when Motion Type is set to Static. Range is -10000 to 10000

  - Z(meters)
    This parameter is used when Motion Type is set to Static. Range is 0 to 10000
  - Velocity Units
    Specify the velocity units of the mobile station. Choices are m/s, Km/h, and mph
  - Virtual Velocity
  - Virtual Phi DoT (degrees ^{o})
    Specify the virtual direction of the mobile station on the XY plane. Range is -180^o to 180^o
  - Virtual Theta DoT (degrees ^{o})
    Specify the virtual direction of the mobile station on the Z axis. Range is 0^o to 180^o
- Power
  - Tx Power (dBm)
- AWGN
  - Enabled?
    Choices are Yes and No
  - C/N Level (dB)
    C/N Range -40 to +40 dB. Resolution 0.01 dB
- Antenna Parameters
  - Antenna Model
    Specify the type of antenna model. Choices are Foreshortening, Angle Independent, and Read from File
  - Antenna Filename1
    Create a unique Filename1
  - Antenna File Format1
    Arrange the columns of data in the selected file to match the expected order
  - Antenna Filename2
    Create a unique Filename2
  - Antenna File Format2
    Arrange the columns of data in the selected file to match the expected order
  - Antenna Filename3
    Create a unique Filename3
  - Antenna File Format3
    Arrange the columns of data in the selected file to match the expected order
  - Antenna Filename4
    Create a unique Filename4
  - Antenna File Format4
    Arrange the columns of data in the selected file to match the expected order
  - Theta Down Tile (degrees ^{o})
    Specify the mechanical tilt of the antenna pattern. Range is -90 to 90 degrees
  - Phi Rotation (degrees ^{o})
    Specify the mechanical rotation of the antenna array. Range is -180 to 180 degrees

- Enable Second Slant?
  Specify whether each antenna array location contains 2 slants. Choices are Yes and No

Channel Model – tab

- Channel ID
- Channel Model
- Downlink Enabled?
  Allows you to enable or disable the DL for selected channel. Choices are Yes and No
- Uplink Enabled?
  Allows you to enable or disable the UL for selected channel. Choices are Yes and No
- Use Drop Modeling?
  Choices are Yes and No
- Use XPR V/H?
  Allows you to turn on and off the use of XPR V/H for the selected channel. XPR is the cross-polarization ratio. V and H are Vertical and Horizontal components.
  Choices are Yes and No
- XPR (dB)
  Specify the cross-polarization ratio, which measures the correlation between the vertical and horizontal elements. Range is 0 to 200 dB
- Line of Sight?
  Specify whether there is line of sight beam between the mobile station and the node.
  Choices are Yes and No
- Decouple LOS/Clusters?
  Specify whether you want to decouple LOS/clusters. Choices are Yes and No
- Use Model
  Specify the recommended 3GPP use model is based on.
- Fading Model
  Specify the fading model you want to use. Choices are Sum of Sinusoids or Filtered Noise
- Path Loss Model
  Specify the path loss model you want to use. Choices are Standard or Custom

Vertex other Use Cases

Outlined in this whitepaper is how Vertex and our MESH software can emulate and model the complexities of MANET environments. Vertex along with other software packages has been used to emulate and model other complex RF environments:

*Dynamic Spectrum Sharing (DSS)
*Maritime Ship to Shore (LOS/NLOS)
*SATCOM
*Electronic Warfare (EW) & Signal Intelligence (SIGINT)
*Phased Array Antenna Beamforming
*5G FR1 & FR2, 4G-LTE, 3G

Want to learn more and schedule a Demo…

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