

Using measurements with the Daintree Networks Sensor Network Analyzer

Application Note AN026



Copyright © 2003–2008, Daintree Networks Inc
All rights reserved

Trademarks and acknowledgements

- ZigBee® is a registered trademark of the ZigBee Alliance.
- 802.15.4™ is a trademark of the Institute of Electrical and Electronics Engineers (IEEE).
- Pentium® is a registered trademark of Intel Corporation.
- Microsoft®, Windows®, and other Microsoft products mentioned herein are trademarks or registered trademarks of Microsoft Corporation.

These trademarks are registered by their respective owners in certain countries only. Other brands and their products are trademarks or registered trademarks of their respective holders and should be noted as such.

Disclaimer

This note and any examples it contains are provided as-is and are subject to change without notice. Except to the extent prohibited by law, Daintree Networks makes no express or implied warranty of any kind with regard to this guide, and specifically disclaims the implied warranties and conditions of merchantability and fitness for a particular purpose. Daintree Networks shall not be liable for any errors or incidental or consequential damage in connection with the furnishing, performance or use of this guide and the examples included.

The software described in this guide is furnished under a license agreement or nondisclosure agreement. The software may be used or copied only in accordance with the terms of those agreements.

No part of this publication may be reproduced, stored in a retrieval system, or transmitted in any form or any means electronic or mechanical, including photocopying and recording, for any purpose other than the purchaser's personal use, without the written permission of Daintree Networks.

Sensor Network Analyzer Release 2.2 (2008-03-27)

About measurements

Measurements are essential during ZigBee development and deployment to ensure that devices meet

- IEEE 802.15.4 and ZigBee standard specification and regulatory requirements
- All performance and reliability claims made by the device manufacturers and suppliers

Daintree's Sensor Network Analyzer (SNA) provides a measurement system that enables quantitative analysis of the operation of the wireless sensor network being observed. A large number of different measurements are available, enabling you to extract the measurements important for any given test scenario. (A complete list of available measurements is provided at the end of this application note.)

About Daintree's Sensor Network Analyzer (SNA)

The SNA combines a powerful protocol analyzer with network visualization, measurements and diagnostics for IEEE 802.15.4 and ZigBee applications. It provides automatic display of network formation, topology changes, and router and coordinator state changes allowing rapid detection of incorrect network behavior and identification of device or network failures.

It also provides a powerful commissioning tool that helps to hide the complexity of the underlying technology, and provides straight-forward configuration, testing and troubleshooting capabilities. Its graphical representations makes it fast and easy for installers to monitor network formation and measure key parameters such as link quality and bindings.

About the 2400E Sensor Network Adapter

Daintree's 2400E Sensor Network Adapter can be used as an active device, which means that under the control of the SNA it is capable of "active analysis."

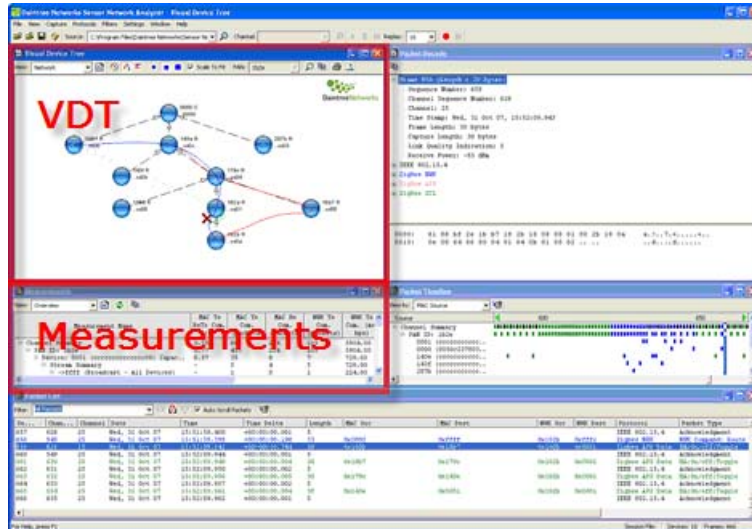
Active devices are able to join an 802.15.4 or ZigBee network, interact with other devices on it, and actively poll devices to gain information not available through passive "sniffing" alone.

Visit www.daintree.net to find out more about Daintree products.



Viewing measurements with the SNA

Measurements are available through the SNA's dedicated Measurements window and also the Visual Device Tree (VDT) and Visual Device Layout (VDL) windows.



The SNA collects measurements on the state of the wireless sensor and control network. The measurements are updated as packets are observed by the analyzer. Measurements are collected per channel, per PAN, per device, and then can be further analyzed based on NWK layer streams or routes, or based on application layer bindings and clusters (message groups).

Measurement Name	MAC Tx ReTx	MAC Tx Cum.	MAC Rx Cum.	NWK Tx Cum.	NWK Tx Cum. (max)	NWK Rx Cum.	NWK Max Latency	NWK Lost Packet Cum
Channel Summary	0.00	174	25	102	840.00	5	11.84	0
PAN ID: laaa	0.00	145	24	102	840.00	5	11.84	0
Device: 0x8825 (00:0d:6f:00:00:06:7..)	0.00	42	8	25	448.00	0	-	0
Stream Summary	-	3	0	3	448.00	0	-	0
->ffff (Broadcast - All Devices)	-	3	0	3	448.00	0	-	0
Bindings Summary	-	1	0	1	224.00	0	-	-
0/0 ZDP	-	1	0	1	224.00	0	-	-
Device: 0x0000 (17:16:15:14:13:12:0..)	0.00	31	5	26	440.00	3	9.60	0
Stream Summary	-	2	2	2	272.00	2	9.60	0
->373d	-	2	2	2	272.00	2	9.60	0
Bindings Summary	-	0	0	0	0.00	0	-	-
Device: 0x6032 (00:0d:6f:00:00:0f:1..)	0.00	40	8	24	840.00	0	-	0
Stream Summary	-	3	0	3	672.00	0	-	0
->ffff (Broadcast - All Devices)	-	3	0	3	672.00	0	-	0
Bindings Summary	-	1	0	1	224.00	0	-	-
0/0 ZDP	-	1	0	1	224.00	0	-	-
Device: 0x373d (00:0d:6f:00:00:0f:1..)	0.00	32	3	27	448.00	2	11.84	0
Stream Summary	-	5	2	5	448.00	2	11.84	0
->ffff (Broadcast - All Devices)	-	3	0	3	448.00	0	-	0
Bindings Summary	-	1	0	1	224.00	0	-	-
0/0 ZDP	-	1	0	1	224.00	0	-	-
->0000	-	2	2	2	136.00	2	11.84	0
Bindings Summary	-	2	2	2	136.00	2	11.84	-
1/240 ZTP2	-	2	2	2	136.00	2	11.84	-

Why these measurements are important

When developing a new application, much of the focus is initially on verifying correct operation of a small number of devices. Typically, developers will build smaller, controlled networks to validate correct behavior of individual devices. These are often run over short periods of time and the number of packets generated is quite limited. Packet (or protocol) analysis is often sufficient.

However, larger systems that are more representative of real deployments will often behave differently. With more devices, routers, and packets, devices are often pushed to greater limits. Longer term tests may be required. Watching individual packets to determine what is happening becomes correspondingly more difficult.

Measurements overcome this by aggregating and summarizing information. For example, in a system of dozens or hundreds of devices, it is often difficult to determine whether one particular device has failed (or is failing). Measurements can show for instance, that a device's retransmission ratio (that is, how often a device must retransmit the same packet before it receives an acknowledgement) is high, indicating that a device is struggling to be heard. Alternatively, if a device should suddenly transmit packets more frequently than normal and thereby prevent other devices from using the airwaves, this would be shown by the measurement system (via Packet Count measurements). Being able to view the whole network through the measurement system helps to prevent incorrect diagnosis. For example, in the previous case the failure might appear to be in the device that cannot send packets, whereas when you look more closely, the reason it can't send packets is because another device is hogging the airwaves.

Where long term tests are required, temporary short-term failures may be missed. A router that failed to route packets over a two-minute interval (potentially rebooting) would be highlighted by the measurement system as having lost packets at some stage during an overnight (or weekend) test.

Measurements provide aggregate and summary information that makes it possible for effective analysis of larger systems and over a longer period of time, ensuring that ZigBee application and devices are built for reliable and scalable operation.

How the SNA collects measurements

The SNA supports both instantaneous and cumulative measurements.

Instantaneous measurements are those that are based only on packets received during the most recently completed sampling interval

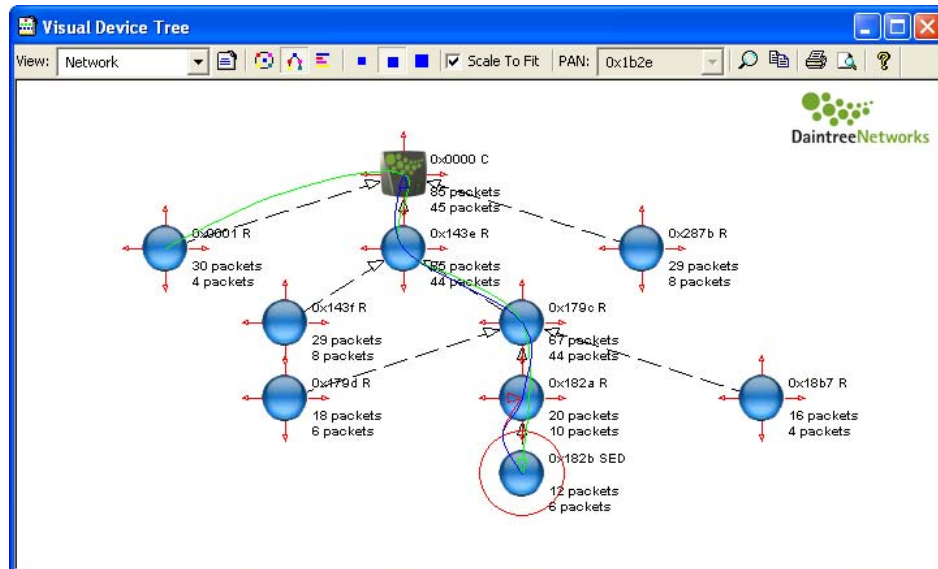
Measurements are calculated over regular intervals called **sampling intervals**. The sampling interval is defined as an integral number of seconds. Each individual measurement will accumulate during the sampling interval before being latched at the end of the interval.

Cumulative measurements are those that are based on all packets received during all sampling intervals since the measurements started.


Depending on the test scenario either or both of these measurement types may be required. The measurement system collects both instantaneous and cumulative for all measurements and allows you to select one or both values for display.

Viewing measurements in the VDT

The SNA's Visual Device Tree (VDT) window provides a graphical representation of the ZigBee network and all devices it contains.

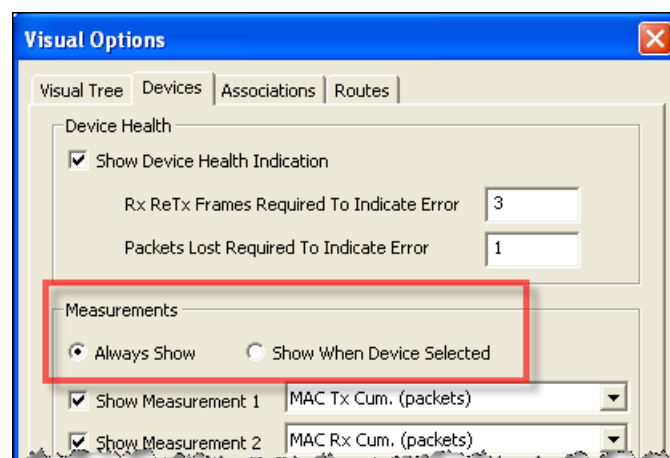


You can select the way in which measurements are shown in the VDT by specifying Visual Options.

1. In the Visual Device Tree window, select the type of **View** you want to configure.
2. From the **Settings** menu, select **Visual Options**, or click the  icon from the Visual Device window toolbar to open the Visual Options dialog box.
3. Select the **Devices** and **Routes** tabs to specify the way in which you want to view measurement details.

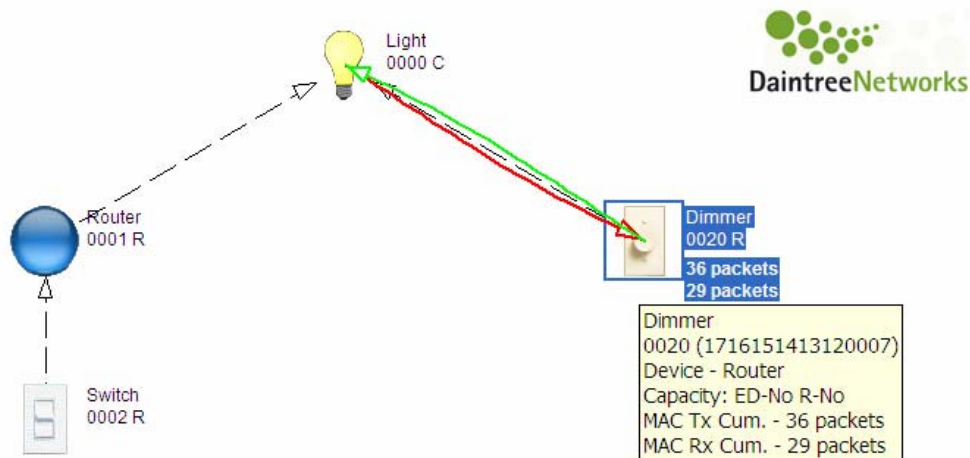
Device measurements

Measurements can be shown associated with a given device. These measurements can be either always shown, or shown only when a device is selected.



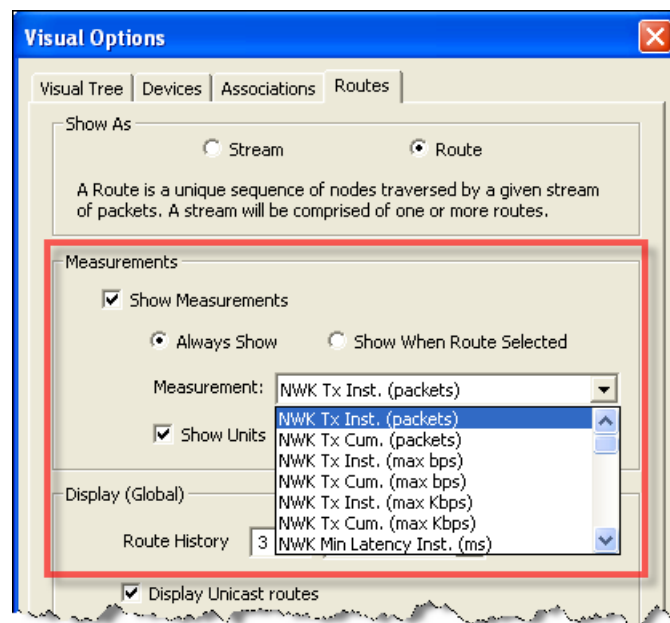
Using measurements with Daintree's SNA

Full details of Device Health and Device Measurements are displayed as flyover help when the mouse is moved over a given device.

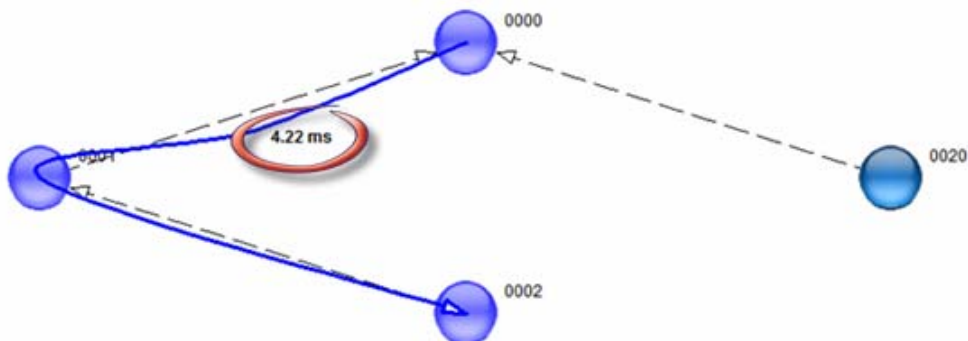


Route measurements

Similar to device measurements, route measurements can be associated with routes.

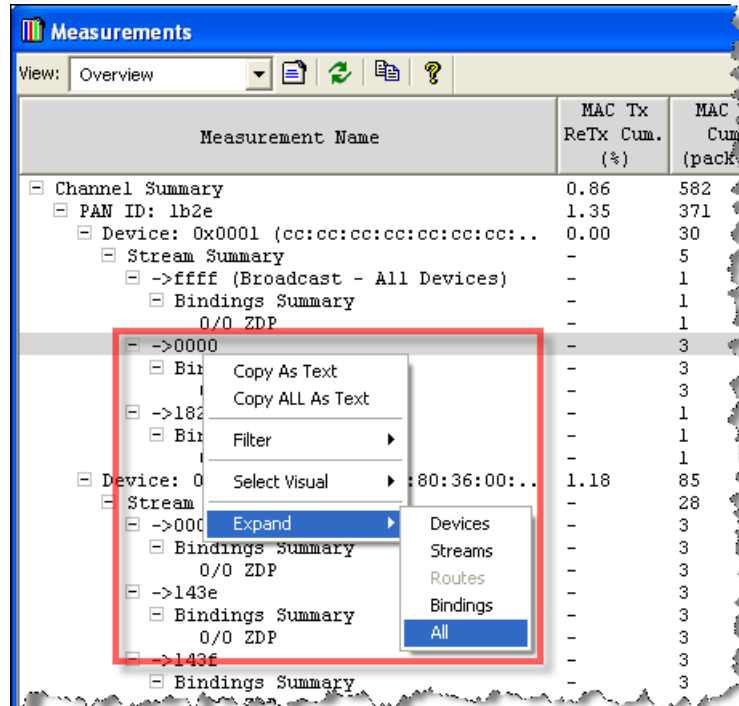


Route Measurements can be shown always for all routes, or only when a route is selected. You can also choose which measurement to display.



Measurements context menus

Each level of the Measurements hierarchy provides a unique right-click context menu. These menus enable the selection (and highlighting) of corresponding items in the Visual Device Tree, or provide shortcut packet filter operations to filter the packets shown in the packet list based on the selected item in the Measurements View. Different context menu items are available for different items.



Right-click context menus are available for the following:

- Devices
- Streams (all of the network layer packets flowing between two devices)
- Routes (all of the network layer packets flowing between two devices along a given path)
- Bindings (all of the APS layer packets flowing between two APS endpoints on two different devices)
- Clusters (a specific class of application layer attributes being exchanged by two APS endpoints on two different devices)

Filter context menu

The Filter context menu options differ depending on the type of item selected:

- **PAN:** Show only packets for the selected PAN
- **MAC:** Apply a filter to select which APS packet details to view:
 - For devices: match all packets where the selected device is the Source, Destination, or either (this will match both short and long addresses)
 - For devices: match when this device has participated in the MAC layer association sequence; this is useful to debug network formation issues

- **NWK:** Apply a filter to select which APS packet details to view:
 - For devices: match all packets where the selected device is the Source, Destination, or either
 - For streams, routes and bindings: match all packets corresponding to this stream (between the given source and destination)
- **APS:** Apply a filter to select which APS packet details to view:
 - For bindings: match all packets flowing from the source endpoint and/or to the destination endpoint
 - For clusters: match all packets on the given cluster between the given source device/endpoint and the given destination device/endpoint

Select Visual context menu

Using this context menu, you can select to view any of the following in either the Visual Device **Tree** or Visual Device **Layout** windows:

- **Device:** Highlight the selected device
- **Source and Destination:** Highlight the source and destination devices for the selected stream or route
- **Route:** Highlight the selected route
- **APS Binding:** Highlight the selected binding

Expand context menu

The Expand right-click context menu is available for the entire Measurements Window and is not specific to different levels of the measurement hierarchy. The Expand menus determine to what level the Measurements hierarchy is expanded and collapsed and hence determines what is shown at any point in time.

The following options are available:

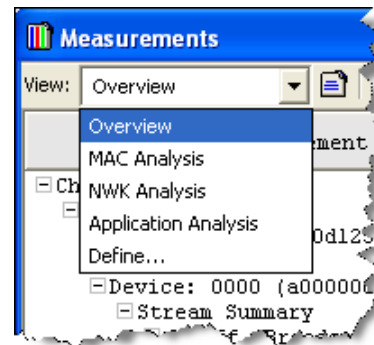
- **Devices:** Show the device level but collapse all others
- **Streams:** Show devices and streams but collapse routes and bindings
- **Routes:** Show devices, streams and routes, but not bindings
- **Bindings:** Show devices, streams and bindings, but not routes
- **All:** Show everything

Other measurements options

Using views

You can select which columns and rows to show in the measurements window. The set of selected columns and rows comprise a **Measurement View**. You can define your own custom views or use the SNA's pre-defined views, and quickly toggle between them. (See the SNA's online help for instructions.)

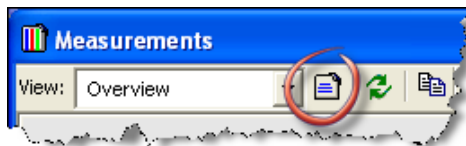
Note: The SNA collects ALL measurements ALL the time, regardless of which measurements are selected to be shown in the current view. Therefore, you can create new views during a measurement session without losing any data.



Refining measurements options

The Measurement Options dialog box allows you refine the current View and select in detail which measurements you do and don't want to show.

1. From the Measurements window **View** list, make sure that the view for which you want to define measurement options is currently selected.
2. From the SNA **Settings** menu, select **Measurement Options** (or you can click the Options icon in the Measurements window):



3. Use the tabs across the top of the Measurement Options dialog box to select the layers for which you want to customize measurements. (See the SNA's online help for instructions.)

Note that tabs are displayed only for those layers that exist in the currently selected View definition.

4. Click **Apply** to apply the settings from the currently displayed tab, or click **OK** to apply the settings from ALL tabs and close the Measurement Options dialog box.

Resetting measurements

Measurements are automatically collected during live capture or playback. They are reset (all counters reset to zero) whenever capture or playback starts. Measurements can also be reset manually during capture or playback without restarting the capture/playback session by clicking the Reset button available from the Measurements toolbar.



Measurement definitions

The following measurement tables provide an explanation of each measurement supported by the Sensor Network Analyzer. Each measurement may support the following sub-measurements:

- Instantaneous: the measurement value for the most recently completed sampling interval,
- Cumulative: the measurement value over the duration of the session since measurements were last started (or reset),
- Byte: packet measurements are typically available as a byte measurements,
 - MAC Layer statistics count the bytes in the MAC Header and Payload
 - NWK Layer measurements count the bytes in the NWK Header and Payload
 - APS Layer measurements count the bytes in the NWK Header and Payload
- Max bps/Kbps measurements show the highest data rate observed where the data rate is calculated over each sampling interval,
 - The Instantaneous version of this measurement shows the observed data rate during the last completed sampling interval,
- Min. measurements show the minimum observed measurement values i.e. one sampling interval showed measurement values lower than all others,
- Max. measurements show the maximum observed measurement values i.e. one sampling interval showed measurement values greater than all others,
- Avg. measurements show the average observed measurement values over all sampling intervals in the current measurement session.

Measurement types

The table also highlights whether each measurement is valid for a particular view type, where:

- **Channel measurements** show accumulated statistics for the entire channel,
- **PAN measurements** show accumulated measurements for a particular PAN,
- **Device measurements** show measurements as they apply to a particular device (on a particular PAN),
 - If a device joins a new PAN, a new measurement entry is created,
- **Stream measurements** show the measurements for those NWK layer data packets sent from a particular source device to a particular destination device,
- **Route measurements** show the measurements for those NWK layer packets that follow a particular path through the network from source to destination,
- **Bindings measurements** show the measurements for those APS layer packets sent from a particular source endpoint to a particular destination endpoint,
- **Cluster measurements** show the measurements for packets sent on a particular bindings corresponding to a particular cluster.

Note that the following measurements tables were correct at the time this application note was published. For the most up-to-date list of available measurements, refer to the **Measurements definitions** appendix in the SNA's online help.

MAC layer

Name	Sub Measurements					Description	Valid on View Type						
	Inst.	Cum.	Byte	Max bps/ Kbps	Min/ Max/ Avg		Chan	Pan	Device	Stream	Route	Binding	Cluster
Tx Packets	✓	✓	✓	✓		Total number of MAC packets transmitted (unicast, broadcast, command and ACK)	✓	✓	✓	✓	✓	✓	✓
Tx ReTx	✓	✓				Total number of transmitted packets observed with a previously transmitted sequence number	✓	✓	✓				
Tx Re Tx %	✓	✓				Retransmissions as a ratio of the total number of packets transmitted	✓	✓	✓				
Tx Command	✓	✓	✓	✓		Total number of MAC packets transmitted (command only)	✓	✓	✓				
Tx Beacon	✓	✓	✓	✓		Total number of MAC packets transmitted (beacon only)	✓	✓	✓				
Tx Broadcast	✓	✓	✓	✓		Total number of MAC packets transmitted (broadcast only)	✓	✓	✓				
Rx Packets	✓	✓	✓	✓		Total number of MAC packets received (unicast only)	✓	✓	✓	✓	✓	✓	✓
Rx ReTx	✓	✓				Total number of received packets observed with a previously transmitted sequence number	✓	✓	✓				
Rx ReTx %	✓	✓				Retransmissions as a ratio of the total number of packets received	✓	✓	✓				
Rx Command	✓	✓	✓	✓		Total number of MAC packets received (command only)	✓	✓	✓				
Rx Power	✓	✓			✓	Signal strength of packet received as measured at the capture node in dBm	✓	✓	✓				
Rx LQI	✓	✓			✓	Signal strength of packet received as measured at the capture node in LQI	✓	✓	✓				

Using measurements with Daintree's SNA

Name	Sub Measurements					Description	Valid on View Type						
	Inst.	Cum.	Byte	Max bps/ Kbps	Min/ Max/ Avg		Chan	Pan	Device	Stream	Route	Binding	Cluster
ACK	✓	✓				Total number of MAC ACKs transmitted	✓						
FCS Errors	✓	✓				Frames with an FCS error	✓						
Decode Errors	✓	✓				Frames that had an error, which meant the SNA couldn't decode them	✓						

NWK layer

All NWK layer measurements exclude MAC layer re-transmissions.

Name	Sub Measurements					Description	Valid on View Type						
	Inst.	Cum.	Byte	Max bps/ Kbps	Min/ Max/ Avg		Chan	Pan	Device	Stream	Route	Binding	Cluster
Tx Packets	✓	✓	✓	✓		Total number of NWK layer transmissions originating from a device, i.e. MAC src == NWK src	✓	✓	✓	✓	✓	✓	✓
Tx ReTx	✓	✓				Total number of transmitted packets observed with a previously transmitted NWK sequence number	✓	✓	✓	✓			
Tx ReTx %	✓	✓				Retransmissions as a ratio of the total number of packets transmitted	✓	✓	✓	✓			
Tx Command	✓	✓	✓	✓		Total number of NWK layer transmissions originating from a device, i.e. MAC src == NWK src (command only)	✓	✓	✓				
Tx Broadcast	✓	✓	✓	✓		Total number of NWK layer transmissions originating from a device, i.e. MAC src == NWK src (broadcast only)	✓	✓	✓				
Tx Multicast	✓	✓	✓	✓		Total number of NWK layer transmissions originating from a device, i.e. MAC src == NWK src (multicast only)	✓	✓	✓				

Using measurements with Daintree's SNA

Name	Sub Measurements					Description	Valid on View Type						
	Inst.	Cum.	Byte	Max bps/ Kbps	Min/ Max/ Avg		Chan	Pan	Device	Stream	Route	Binding	Cluster
Routed Packets	✓	✓	✓	✓		NWK layer frames routed through a device, i.e. MAC dest != NWK dest	✓	✓	✓				
Lost Packets	✓	✓				NWK layer transmissions that don't reach their destination	✓	✓	✓	✓	✓		
Rx Packets	✓	✓	✓	✓		Total number of NWK layer transmissions arriving at their destination, i.e. MAC dest == NWK dest	✓	✓	✓	✓	✓	✓	✓
Rx ReTx	✓	✓				Total number of received packets observed with a previously transmitted NWK sequence number	✓	✓	✓				
Rx ReTx Ratio	✓	✓				Retransmissions as a ratio of the total number of packets received	✓	✓	✓				
Rx Command	✓	✓	✓	✓		Total number of NWK layer transmissions arriving at their destination, i.e. MAC dest == NWK dest (command only)	✓	✓	✓				
Route Latency	✓	✓			✓	The amount of time a NWK layer transmission takes to reach its destination	✓	✓	✓	✓	✓	✓	✓
Duplicate Hop Packets	✓	✓				NWK layer packets detected with the same src, dest, and seq num on the same MAC layer hop	✓	✓	✓	✓	✓		

APS layer

All APS layer measurements exclude MAC layer and NWK layer re-transmissions.

Name	Sub Measurements					Description	Valid on View Type						
	Inst.	Cum.	Byte	Max bps/ Kbps	Min/ Max/ Avg		Chan	Pan	Device	Stream	Route	Binding	Cluster
Tx Packets	✓	✓	✓	✓		Total number of APS layer transmissions originating from a device, i.e. MAC src == NWK src	✓	✓	✓	✓	✓	✓	✓
Tx ReTx	✓	✓				Total number of transmitted packets observed with a previously transmitted APS sequence number				✓		✓	✓
Tx ReTx %	✓	✓				Retransmissions as a ratio of the total number of packets transmitted				✓		✓	✓
Tx Command	✓	✓	✓	✓		Total number of APS layer transmissions originating from a device, i.e. MAC src == NWK src (command only)	✓	✓	✓	✓	✓	✓	✓
Tx Broadcast	✓	✓	✓	✓		Total number of APS layer transmissions originating from a device, i.e. MAC src == NWK src (broadcast only)	✓	✓	✓	✓	✓	✓	✓
Tx ACK	✓	✓				Total number of APS layer transmissions originating from a device, i.e. MAC src == NWK src (APS ACK)	✓	✓	✓	✓	✓	✓	✓
Rx Packets	✓	✓	✓	✓		Total number of APS layer transmissions arriving, i.e. MAC dest == NWK dest	✓	✓	✓	✓	✓	✓	✓
Rx Command	✓	✓	✓	✓		Total number of APS layer transmissions arriving, i.e. MAC dest == NWK dest (command only)	✓	✓	✓	✓	✓	✓	✓
Rx ACK	✓	✓				Total number of APS layer transmissions arriving, i.e. MAC dest == NWK dest (ACK only)	✓	✓	✓	✓	✓	✓	✓