Wi-Fi CERTIFIED Data Elements™
Technology Overview

January 2024

Introduction

Wi-Fi® is the dominant technology in home networking[1]. The increasing reliance on connected devices is convincing service providers of the need to enhance the quality of service of Wi-Fi networks and deploy the latest generation of Wi-Fi 7 to increase capacity and reduce latency. Wi-Fi CERTIFIED Data Elements™ is a Wi-Fi Alliance® certification that provides standardized key performance indicators (KPIs) for Wi-Fi networks and has been augmented with the latest Wi-Fi 7 metrics to enable service providers to proactively improve network efficiency and latency. Service providers implementing Wi-Fi Data Elements™ devices can use the information gathered to improve technical support, offer differentiated service, and increase customer satisfaction.

To appropriately support the wide variety of devices in the home as well as consumer applications such as video streaming and gaming, service providers need better visibility into customer Wi-Fi networks. Wi-Fi Data Elements establishes a standardized data model built specifically for Wi-Fi networks that encompasses hundreds of KPIs that describe capability, diagnostic, and optimization information, such as PHY rates, airtime utilization, and retry rates for Wi-Fi 7 and operation of Wi-Fi CERTIFIED QoS Management™. This information provides visibility to customers' Wi-Fi networks, enabling support departments and analytic engines to quickly obtain, analyze, and respond to these dynamic Wi-Fi environments.

Standardizing the data model that captures Wi-Fi network conditions benefits network operators through better network visibility of existing deployments and opportunities for managed Wi--Fi offerings. With the partnership of Broadband Forum including Wi-Fi Data Elements in TR-181, an even larger group of diverse companies is exposed to the common platform of Wi-Fi visibility. Diagnostic and analytics tool vendors also benefit by gaining the ability to develop tools to a concise, standardized data model, eliminating the need for proprietary solutions and reducing barriers to entry.

Wi-Fi Data Elements is complementary to intelligent multiple access point (AP) networks such as Wi-Fi CERTIFIED EasyMesh®. Maintaining good performance in multi-node Wi-Fi networks will improve the user experience, resulting in customer loyalty and opportunities for additional equipment purchases.

This document provides an overview of the Wi-Fi Data Elements program. Further details, including specifics about the data model and each of the parameters, may be found in the Wi-Fi Data Elements Specification.

Key uses for Wi-Fi Data Elements

Wi-Fi Data Elements provides information on the most important aspects impacting Wi-Fi network performance. This information may be leveraged by diagnostics and analysis tools to help operators maintain optimum Wi-Fi performance and reduce the time required to diagnose network issues. In many cases, issues can be resolved before the customer is even aware of a problem or by the user themselves.

Observability on deployment of new features

Many operators are now starting to deploy the latest generation of Wi-Fi 7 to their customers. With the concurrent availability of the industry standard data model supporting Wi-Fi 7, operators can readily obtain key insights on how the new equipment/technology is benefiting customers. Similarly, as operators enable the negotiation of Wi-Fi QoS Management™ features, operators can readily observe how station (STA) behavior improves. Wi-Fi Data Elements provides visibility whether there is a single AP or a mesh in the home.

Self-help diagnostic application

Operators may develop and deploy a diagnostic application based on Wi-Fi Data Elements, which users can leverage to make network changes and diagnose if these changes resolve an observed issue. In cases where this diagnostic

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does not resolve the issue and the user contacts the operator to seek assistance, the Wi-Fi Data Elements-based application provides technical support personnel with the details of steps taken in order to further assist the user.

Remote Wi-Fi troubleshooting

When a customer contacts their service provider, Wi-Fi Data Elements enables the technical support agent to access current and historical performance data for diagnosis. Common issues include interference from other sources within the network, coverage or configuration challenges, and STA capabilities. Technical support agents can quickly identify the issue based upon the information from the network and can recommend a specific course of action, such as channel or band change.

Resolving coverage and hardware issues

In some environments, a Wi-Fi network may be expected to cover more space than it is designed to, particularly in home networks. When a customer calls technical support for intermittent or slow service, the support agent is able to review data captured from the Wi-Fi Data Elements enabled device and determine whether there is sufficient signal strength for the coverage area. When a support agent observes that the customer's devices are routinely connecting at low received signal strength indicator (RSSI) values or low connection speeds (via low Modulation Coding Scheme), the agent can recommend additional Wi-Fi hardware such as a Wi-Fi EasyMesh™ device, which will address the coverage issues. This benefits the user, with an opportunity to improve their service by adding a device of their choice, as well as the service provider, who has the opportunity to sell additional equipment.

Proactive problem solving

Internet service providers (ISPs) have support systems that monitor and analyze network performance data captured from Wi-Fi devices. Wi-Fi Data Elements standardizes access to Wi-Fi drivers, so support systems no longer need to negotiate with each system on chip (SoC) vendor to retrieve KPIs. These ISP systems can access the data model and trigger an alert when Wi-Fi service performance is impacted. For instance, an alert could be sent to the technical support group of the ISP if an apartment building is experiencing high frame retry rates. Using Wi-Fi Data Elements with diagnostics and support tools, the system can indicate that a wide-band interference source may have been activated, and further investigation and troubleshooting can proceed even before a customer notices an issue.

How Wi-Fi Data Elements works

Definitions

The key components of Wi-Fi Data Elements include the data model, collector, and agent.

Data model

The data model outlines the names, definitions, and hierarchy for Wi-Fi diagnostics and configuration parameters. These key metrics help assess the Wi-Fi network status and connection quality and include such items as radio and channel scan results, devices on the network, and neighbor reports.

Collector

The role of the Wi-Fi Data Elements collector is to retrieve the elements in the standardized data model and make it available for analysis or diagnostics. The collector receives the network information from a Wi-Fi Data Elements agent and sends it to the specified group, typically at the service provider. The collector is software that resides on a device in the operator back office management system. The collector may also act as a configuration server, sending network changes down to the agent.

> **DATA MODEL USE**
>
> Data model information can be available to the user, but more likely will be sent to the service provider or operator.
>
> Once received, diagnostic and analytics tools are applied to determine the network's health and whether action is needed to ensure good Wi-Fi service.

Agent

The Wi-Fi Data Elements agent populates the data model and makes the network information available to a Wi-Fi Data Elements collector. The software-based agent may reside inside a gateway, a Wi-Fi EasyMesh controller, or an AP.

Topologies

Wi-Fi Data Elements can be utilized in both single AP and multiple AP networks. In single AP networks, the Wi-Fi Data Elements agent interacts with the Wi-Fi drivers of a standalone AP to populate the standardized data model. The Wi-Fi Data Elements agent in the AP sends that information to the Wi-Fi Data Elements controller. In Wi-Fi EasyMesh networks with multiple APs, the Wi-Fi Data Elements agent interacts with the Wi-Fi EasyMesh controller to populate the data model and then send the information to the Wi-Fi Data Elements collector.
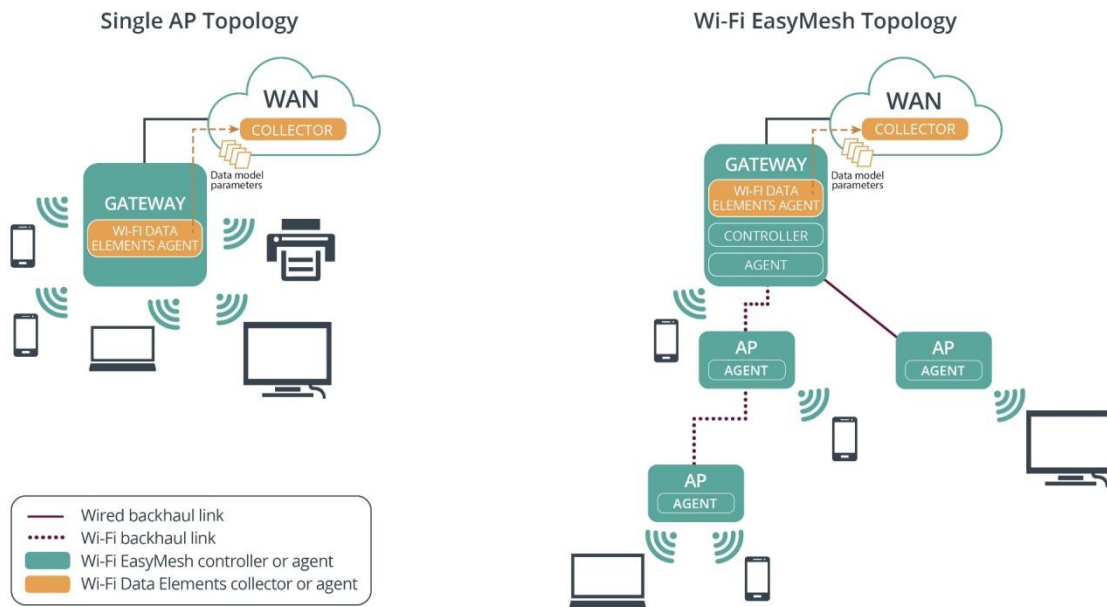

Figure 1. Wi-Fi Data Elements supports both single AP (left) and Wi-Fi EasyMesh multiple AP (right) system topologies

Process

Upon association of a device, disassociation of a device, failed connection attempt from a device, and at times as defined by the service provider while the network is running, the Wi-Fi Data Elements agent records the data model. Information is gathered rapidly and timestamped without use of significant network resources. The Wi-Fi Data Elements collector retrieves the accumulated data from the Wi-Fi Data Elements agent, which helps the provider build a picture of the network status. The visibility gained by the provider regarding network conditions surrounding a reported issue enables support staff to isolate network issues more easily and suggest recommended actions to the customer.

A powerful tool to improve the Wi-Fi user experience

A 2019 industry study on the role of Wi-Fi in home broadband[2] establishes that users require a good Wi-Fi experience to be satisfied with broadband service providers. One of the most important characteristics of high-quality broadband service is a good Wi-Fi signal in every room. Recommendations to service providers include

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[2] *Ovum, 2019*

investing in data and analytics tools to measure Wi-Fi network performance. This should reduce the number of support calls regarding Wi-Fi issues, drastically reduce the time each support agent spends on a call, and help the service provider identify opportunities sell additional equipment — all while inspiring loyalty in their customer base because they deliver a better Wi-Fi user experience. Wi-Fi Data Elements provides the data required to provide the improved Wi-Fi user experience.

Data model organization

Wi-Fi Data Elements was especially designed to organize the complexities of modern Wi-Fi networks. Previous attempts at data models tended to assume a simple network structure of a single device with one radio operating one network, or a basic service set (BSS). Wi-Fi Data Elements recognizes that Wi-Fi coverage is often provided by multiple devices for delivering Wi-Fi service in a single home. Each of the Wi-Fi devices likely has multiple radios — at least one in the 2.4 GHz band and one or more in the 5 and 6 GHz bands. Each radio hosts multiple Wi-Fi networks (BSSs) such as the home user's private network, the home user's guest network, and one or more operator community networks. On each of those networks, a variety of STAs are associated or attempting to associate. Over time, STAs will roam or be steered from one radio to another radio or device. Additionally, the data model covers the elements necessary for Multi-Link Operation, as introduced by Wi-Fi 7 (Figure 2).
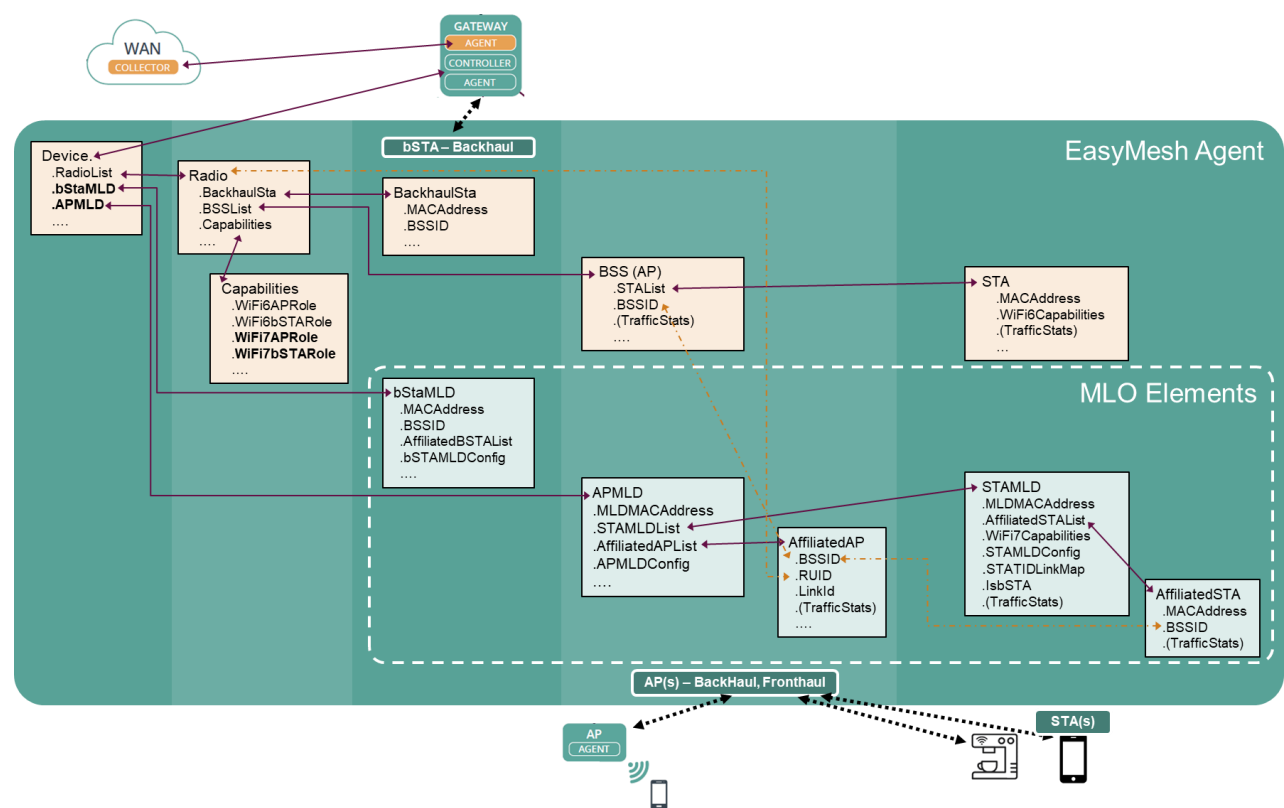

Figure 2. Data model for multi-link operation (MLOs)

The Wi-Fi Data Elements hierarchy encompasses the increasingly granular information of all those connections as shown in Figure 3.
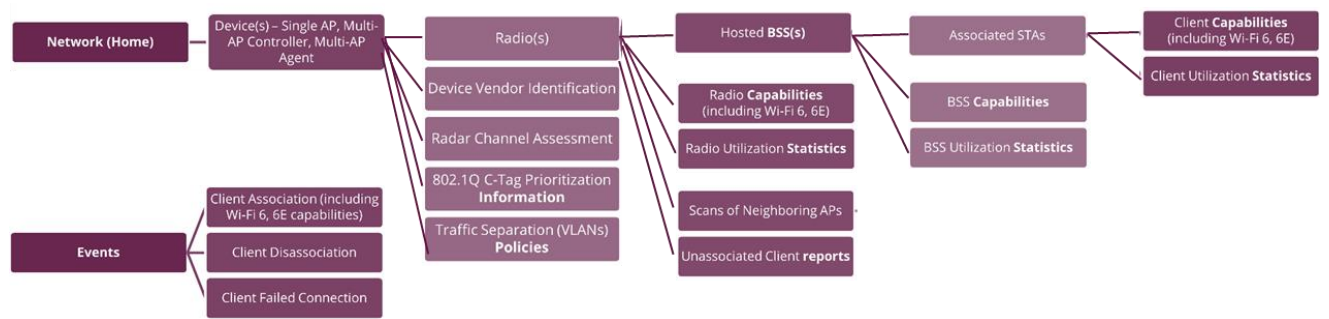

Figure 3. Wi-Fi Data Elements model organization

In addition to its network, Wi-Fi Data Elements provides extensive information about the environment. Each radio can provide information and characteristics of other APs operating in the vicinity in ScanResults. Similarly, if a STA is in the vicinity, its attempts to join one of the networks are collected in Events. If a radio is operating or intending to operate in a 5 GHz radar channel, Channel Availability Check (CAC) information can be provided as shown in Figure 4.
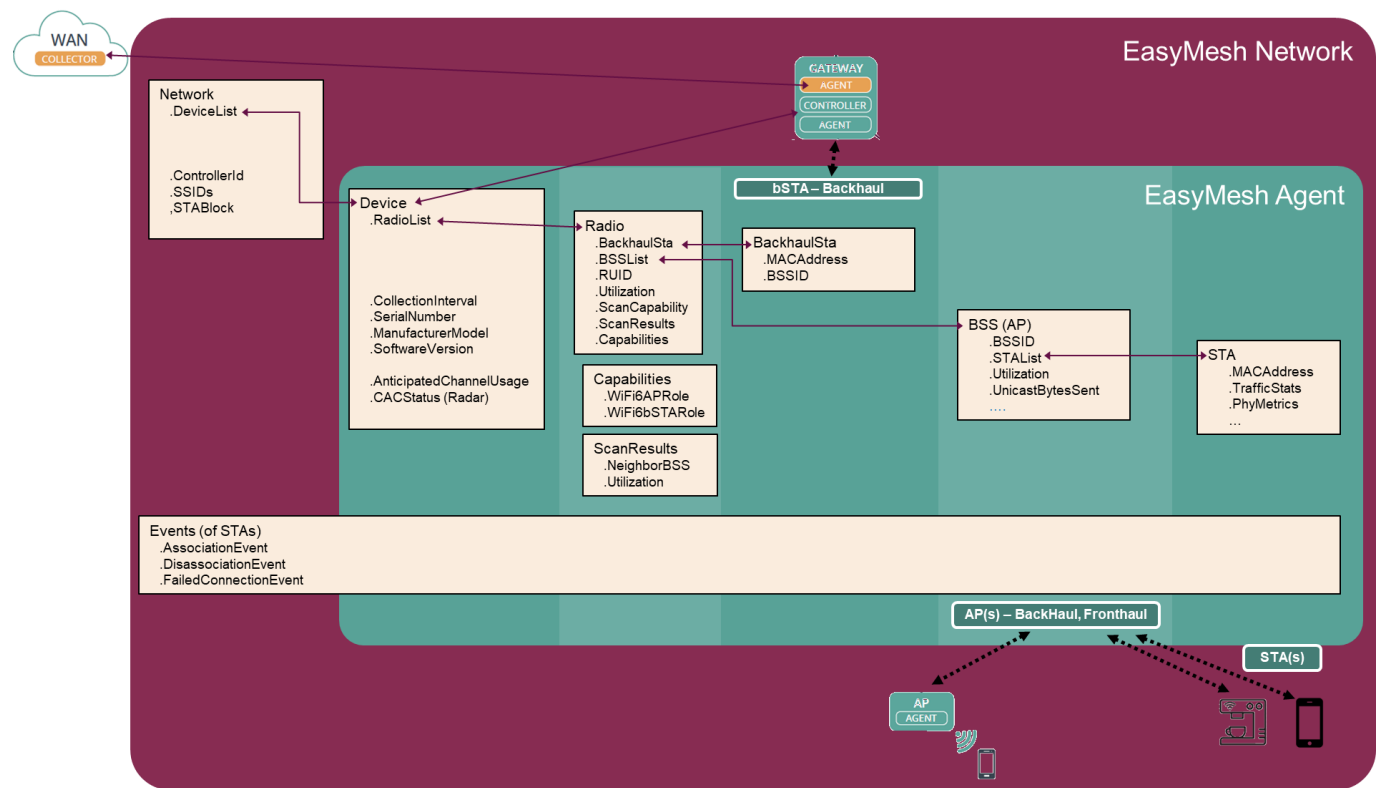

Figure 4. Environment information in Wi-Fi Data Elements

Free airtime (utilization) is an important metric for network operation. Wi-Fi Data Elements provides utilization statistics at multiple levels of granularity — radio, BSS, and STA. This allows precise identification of in-network versus out-of-network utilization to determine specific mitigation strategies.

Data model integration

To unlock the value of Wi-Fi Data Elements in operator management systems, the Wi-Fi Data Elements model has been integrated into the industry TR-181 Device Data Model from Broadband Forum. This allows operators using TR-069 or TR-369 – User Services Platform (USP) based tools to take advantage of the Wi-Fi Data Elements model.

Wi-Fi Data Elements was incorporated in TR-181 Issue 2.13 in September 2019. Issue 2.15 added the elements related to Wi-Fi 6 and Wi-Fi 6E in January 2022. Wi-Fi 7 MLO and Wi-Fi QoS Management from Wi-Fi Data Elements is targeted for TR-181 Issue 2.17.

Examples of how Wi-Fi Data Elements data is utilized

PHY rates: The pulse of the network

An indicator of Wi-Fi performance is the underlying physical layer (PHY) rate, which is the result of all data a STA or AP uses to decide how to send a wireless frame. The most frequent causes of low PHY rates are interference, low signal strength, and legacy STAs on the network. Poor PHY rates can result in poor performance for everybody in the network. Wi-Fi Data Elements allows collecting the PHY rates of STAs, BSSs, and radios over time.

Figure 5. Wi-Fi Data Elements helps providers keep track of Wi-Fi network PHY rates

Figure 5 shows the change in PHY rate as a mobile device moves throughout a home network. When a PHY rate goes below an acceptable level, it could indicate the need for steering to another radio. If low PHY rates persist over time, it may indicate the need for additional APs or for the user to update network or STAs for optimum performance.

Example data elements utilized:

STA.LastDataUplinkRate: The PHY rates most recently used for the transmission of physical layer protocol data units (PPDUs) from the STA to the AP

STA.LastDataDownlinkRate: The PHY rates most recently used for the transmission of PPDUs from the AP to the STA

Low free airtime: Slow Wi-Fi

Free airtime provides one view of the health of the Wi-Fi network. Sufficient free airtime is needed for all devices to be able to perform as expected. Low free airtime is an indication that the channel utilization is getting saturated, which will limit throughput and the number of additional STAs able to associate to the network.

Figure 6 shows spikes in interference that likely cause network performance issues. The Wi-Fi Data Elements model captures network conditions so that the service provider analytics tools can identify these spikes. Some service providers may have an alert set up once free airtime is below a certain threshold. This enables the support team to proactively become aware of a potential issue and begin problem solving before a customer calls in. Beyond interference, larger time periods showing a lack of free airtime could point to a change in the network such as significant amounts of STAs associating and stressing resources, excessive data traffic, older devices that may be using too much airtime, or poor coverage which may be solved with additional customer premises equipment (CPE) purchases. A service provider could choose to guide the AP to change channel or investigate further to identify other potential sources of interference.

Figure 6. Wi-Fi Data Elements helps diagnostic tools visually represent airtime activity

Example data elements utilized:

Radio.Utilization: The current total channel utilization on the current primary channel

Radio.Transmit: The percentage of time the radio has spent on individual or group addressed transmissions by the AP

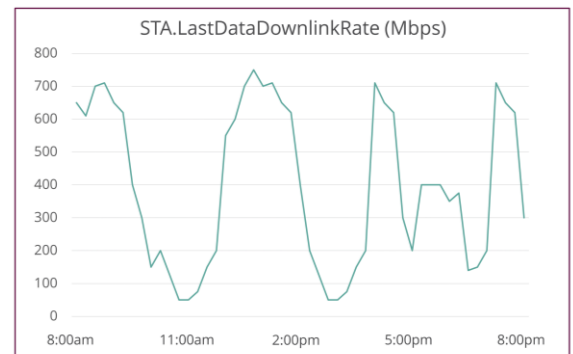Radio.ReceiveSelf: The percentage of time the radio has spent on receiving individual or group addressed transmissions from any STA operating on that radio

Radio.ReceiveOther: The percentage of time the radio has spent on receiving valid IEEE 802.11 transmissions that are not associated with any BSS, or network, operating on that radio

High retry number: Significant insight to Wi-Fi network health

When Wi-Fi devices communicate with an AP and the AP does not respond, the device keeps trying to communicate. Service providers greatly benefit when they have visibility to the number of retries a device makes, as this count provides significant insight into impending problems and presents an opportunity to identify an issue before the customer does. A small number of dropped frames may not affect service; however, high retries combined with high RSSI can indicate hidden node issues, while high retries combined with low RSSI can indicate coverage issues. The image in Figure 7 shows a spike in retries around 11:00am. If this trend continued, the service provider could choose to request the AP to change channels or investigate possible sources of interference.

Historic retry data enables service providers to identify a problem before it affects the customer. Wi-Fi Data Elements provides this data in its standardized data model.

Figure 7. Wi-Fi Data Elements helps diagnostic tools identify high retry attempts

Example data elements utilized:

STA.PacketsSent: The total number of packets transmitted to the associated STA

STA.RetransCount: The total number of retransmitted packets to the associated STA; two retransmissions of the same packet results in the counter incrementing by two

STA.ErrorsSent: The total number of outbound packets that could not be transmitted to the associated STA due to errors, possibly due to the number of retransmissions exceeding the retry limit

Interference from neighboring networks

Interference is caused by many things, from cordless phones to microwave ovens to neighboring networks. The primary method for reducing interference is channel selection. A channel scan can determine the quality, strength, and utilization of neighboring networks. By leveraging information in the data model, the operator can choose to direct the AP to the best channel.

Example data elements utilized:

ChannelScan.NeighborList: The list of neighboring networks discovered in a channel scan

NeighborBSS.SignalStrength: An indicator of the RSSI of the Beacon or Probe Response frames of neighboring networks

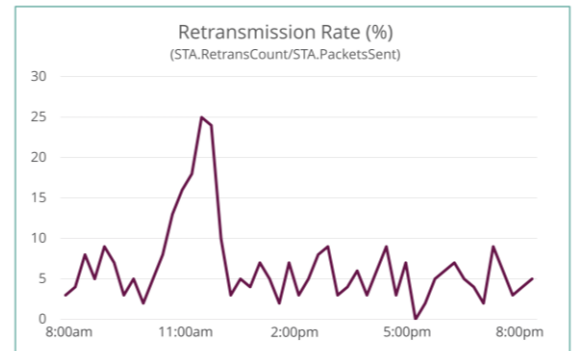ChannelScan.Utilization: The current channel utilization measured by the radio on the scanned 20 MHz channel

Multi-generational network management

Wi-Fi Data Elements incorporates Wi-Fi 7 technology performance data collection as well as collecting Wi-Fi 6E, Wi-Fi 6, Wi-Fi 5, and Wi-Fi 4 network data. This provides operators the metrics needed to manage the complexity of a multi-generational network to maximize deterministic quality of service (QoS), minimize latency, and enable coordinated scheduling through anticipated airtime utilization.

Example data elements utilized:

WiFi7Capabilities

The interconnection of AP MLD and station (STA) MLD and their Affiliated APs and Affiliated STAs

Capabilities.WiFi6APRole: The capabilities of a Wi-Fi Data Elements agent radio that is Wi-Fi 6 AP capable

Capabilities.WiFi6bSTARole: The capabilities of a Wi-Fi Data Elements agent radio that is Wi-Fi 6 STA capable acting as a backhaul STA in the Wi-Fi EasyMesh environment

STA.WiFi6Capabilities: The capabilities of a Wi-Fi 6 STA that is associated to a Wi-Fi 6 capable Wi-Fi Data Elements agent radio

Mechanism for monitoring multiple AP network performance
Wi-Fi Data Elements also collects network policies that are in effect in a Wi-Fi EasyMesh network that further enhance an operator's ability to monitor residential Wi-Fi EasyMesh network performance.

Example data elements utilized:

Device.TrafficSeparationPolicy: The currently configured traffic separation policy, i.e., SSID-to-VLAN ID (VID) mapping, configured by the Wi-Fi EasyMesh controller for each fronthaul radio of the Wi-Fi EasyMesh agent

Device.Default8021Q: The default 802.1Q settings used in a Wi-Fi EasyMesh agent

Summary

The home network represents great opportunity for service providers. Since Wi-Fi is the primary connectivity technology in the home, consumers demand better Wi-Fi service. Wi-Fi networks have gained complexity due to the number and types of devices connected: video requires more bandwidth, gaming requires lower latency, and users require good connection across the entire network. In the past, operator responsibility for the Internet connection ended at the wired router/gateway. Now, providers approach Wi-Fi in a more holistic fashion by including Wi-Fi routers in their consumer premise equipment options.

For service providers to offer the Wi-Fi experience users expect, it is critical that they obtain more visibility into Wi-Fi network behavior. Wi-Fi Data Elements devices provide this visibility which helps service providers efficiently manage and maintain Wi-Fi network performance, even as device types and numbers increase. Through a standardized Wi-Fi data model providing KPIs and remote configuration capabilities that assist operators and support teams in proactively troubleshooting Wi-Fi issues, Wi-Fi Data Elements is key to optimizing Wi-Fi networks to provide better user experiences and drive customer loyalty.

About Wi-Fi Alliance®

www.wi-fi.org
Wi-Fi Alliance® is the worldwide network of companies that brings you Wi-Fi®. Members of our collaboration forum come together from across the Wi-Fi ecosystem with the shared vision to connect everyone and everything, everywhere, while providing the best possible user experience. Since 2000, Wi-Fi Alliance has completed more than 80,000 Wi-Fi certifications. The Wi-Fi CERTIFIED® seal of approval designates products with proven interoperability, backward compatibility, and the highest industry-standard security protections in place. Today, Wi-Fi carries more than half of the internet's traffic in an ever-expanding variety of applications. Wi-Fi Alliance continues to drive the adoption and evolution of Wi-Fi, which billions of people rely on every day.

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