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Broadband
Alliance



Access Network Metrics

Leveraging Key Indicators to Quantify Network Performance

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1. Executive Summary

Wi-Fi devices make roaming decisions based on extremely limited information, which may lead to a poor quality of experience (QoE) and negatively affect customer perceptions. By analysing standard Wi-Fi metrics and providing guidance, a Wi-Fi device or provider will be far better equipped to make a roaming decision that will positively impact the user. This paper looks at the need for explicit QoE evidence, the use cases where this will benefit both users and providers, an example of the key metrics needed, and a path forward to continue this work into the necessary calculations and methods of communicating these data.

2. Introduction

Wi-Fi benefits from being affordable, easy to deploy, and nearly ubiquitous. Spectrum is free, equipment is commoditized, a robust ecosystem of skilled service providers and technical professionals exists, and nearly every wireless device produced includes Wi-Fi.

The downside of unregulated Wi-Fi is that networks can be deployed by anybody, in any location, without regard for the RF environment or attention to implementation details necessary for a secure, high-performing network. As a result, Wi-Fi has earned a reputation of being unreliable. While the adoption of Passpoint® as a standard for device authentication has largely addressed security concerns, it does not address the quality concerns unfortunately associated with Wi-Fi.

The WBA Access Network Metrics working group aims to develop a framework for communicating Wi-Fi access network Quality of Experience (QoE) to interested stakeholders. This includes mobile operators utilizing commercial cellular off-load, participants in roaming consortiums (e.g., [WBA OpenRoaming™](#)), settlement free Passpoint services, or enterprises seeking to reliably connect to 3rd party Wi-Fi networks. The ultimate objective is to define a framework that permits:

- the production of multi-vendor metrics from any Wi-Fi deployment;
- the exposure of such metrics by Wi-Fi equipment;
- the signalling of such metrics between Wi-Fi equipment producers and metric consumers; and
- the analysis and aggregation of such metrics by consumers, which may in turn expose processed metrics to other consumers.

where one of the functions of such consumers can be to help guide Wi-Fi network selection.

This briefing summarizes the working group's intended direction and progress to date. It covers individual access network key performance indicators (KPI) that most broadly reflect quality of experience, and specific use cases where a characterization of access network quality will be most valuable. As achieving "quality" in an access network evolves with each release of the Wi-Fi specification,

it is envisioned that this topic will become a standing focus for the WBA, either as its own working group or as a subcommittee of other WBA working groups focused on Wi-Fi network quality of experience.

3. Introduction to Concepts: Use Case Scenarios, Metrics Needed and Users of Metrics

In the first phase of the project, the objective is to produce a method for characterizing and expressing Wi-Fi access network quality metrics that is practical to implement and utilizes existing performance measurement capabilities. The initial expression is to be derived from the performance impacting attributes most common to popular use cases, for use by the recipient as a network selection decision making tool. These use cases are described here.

3.1 Network selection in presence of multiple options (pre-Auth) / IDP Roaming Decision

The intent of this use case is to provide Identity Providers (IDP) with access network quality information for the Wi-Fi network an end-user device is attempting to authenticate to, so that an access authorization can be made according to the IDP's policies for access network quality. In the first phase, the access network quality data is envisioned to be available in Remote Authentication Dial-In User Service (RADIUS) attributes only after an end-user device has initiated an authenticate attempt (i.e., Access-Request) and possibly also in Accounting-Request messages that could allow the IDP to understand access network quality over the course of an existing connection.

Whereas an end-user device may already be able to autonomously determine a subset of access network quality metrics, in the future it is envisaged that the end-user device could be enhanced to be able to consume metrics exposed by the Wi-Fi infrastructure, including when the device is in a pre-attached state. Such infrastructure derived metrics can then be used by the end-device when considering network selection and/or how the device operates when simultaneously attached to multiple networks.

3.2 Session Metrics

Simple metric capture isn't enough to form a clear picture of QoE, as session behaviors must be accounted for. For example, an end-user device may be moving to the edge of coverage and looking to actively roam from the first Access Point (AP) onto a second AP. This, from the first AP's perspective, would look like a poorly performing device, when in fact the device is behaving normally and appropriately. Another example is an end-user device with older technology, e.g., an 802.11n device in a Wi-Fi 6 network. This may appear to the AP as a device with a bad QoE, but the access network is not the cause.

There are scenarios, like the two described above, that will need to be weighted appropriately when defining access network metrics, to not unnecessarily penalize the access network.

3.3 Compliance with XLAs (Experience Level Agreements)

This use case is focused on measuring compliance with an Experience Level Agreement offered by an Access Network Provider (ANP) to their customers, including one or more of their managed service providers. Measurement and reporting are envisioned at the venue/location level. It is intended as a reporting mechanism and not a real-time monitoring solution, though by shortening the reporting interval it could be used by an ANP who lacks other, more robust tools, to monitor the quality of experience on their network.

3.3.1 OpenRoaming Service Levels

The classification of an OpenRoaming access network (e.g., Silver, Bronze) based on its performance is an example of access network quality measurement being used to support an XLA/SLA. The proposed QoE score and supporting metric details could standardize this qualification of OpenRoaming networks.

For more information on OpenRoaming Tiers please see: <https://www.ietf.org/archive/id/draft-tomas-openroaming-01.html>.

3.4 Application awareness of network QoS

Multiple use cases, including Industry 4.0, telecommunications, the metaverse and others require the network Quality of Service (QoS) to be exposed. This data can be used for multiple purposes such as input into roaming, switching, network slicing, convergence, power efficiencies, and aggregation decisions as well as application decisions of when and where to run and how best to use the available networks. Understanding the noise, jitter, amount of bandwidth in use or available, the number of devices connected and access network configuration give rise to more efficient use of the network. Whereas an application may look to autonomously estimate the network QoS, e.g., using metrics derived from application traffic or specific probes, there is an opportunity to expose access network metrics to applications. The API to get this information may come as an operations and management interface, i.e., a rest API for each attribute or for individual attributes depending on the implementation required.

3.5 Voice over Wi-Fi / ePDG

Poor access network quality is most noticeable in real-time, two-way communications such as a voice conversation. Understanding the access network quality, particularly latency and jitter, is a direct reflection of Quality of Experience for this category of applications. In the initial phase, providing access network quality to the provider of network-provided voice services can enable an authorization decision on attachment to a Passpoint-enabled Wi-Fi network. Going forward, exposing this access network quality to the end-user device (or over-the-top applications) directly would enable an evaluation of candidate network quality as an input to roaming decisions.

3.6 Access Network Provider Use Cases

It is common for network monitoring to reflect the health of a network based on averages across sessions and across an access network. Frequently, network monitoring reports that a network is in good health even when a user's connected experience is poor. Characterizing QoE in the access network at the session level would complement the use of existing KPIs characterizing network QoS and provide Access Network Providers a valuable KPI that could be used to trigger alerts or other actions when QoE falls below a policy-based threshold. A history of QoE score and supporting metrics can be logged to provide periodic reporting in support of service level commitments from managed service providers to their network owners as well as historical data for troubleshooting a reported experience.

3.6.1 ANP Motivation

Digital transformation is putting a premium on the connected user experience and corresponding analytics across all settings including hospitality, transportation, retail and others. Acknowledging that sharing access network quality with third parties does create the potential for operational exposure, it is also always in the best interest of the ANP to understand and deliver a high-quality connected experience to its customers. Benefits to the ANP come in the form of customer satisfaction and loyalty, improved operational efficiency, and the ability to monetize commercial off-loading. Poor connectivity compromises each of these.

3.6.2 Acceptable Use

It is important that ANPs have agreements with the partners with whom they share access network quality information that govern how that data can be used.

4. Metrics (KPIs) – Attributes and Measurements (Phase 1)

The following list represents a starting point of what data needs to be captured from a Wi-Fi network to create a quality evaluation. The metrics chosen are both generally available and have the most impact on network performance. We anticipate this list to be modified or expanded as we proceed in phase 2, but these KPIs establish a solid example of what is important to capture. PHY/RF offers the most discrete measurement of the Wi-Fi access network but may not be the best representation of connected experience across a venue. Measuring certain common IP performance characteristics can be more indicative of connected experience as they reflect a broader end-to-end performance. In short, we will ideally have KPIs from layers 1-4, giving us a holistic view of network performance. Taken together, ANPs can isolate access network health as the potential source of a poor connection experience. Where Wi-Fi is a contributing factor, the attributes in focus for the first phase of the project help to inform a network operator of performance impacting issues.

PHY/RF Health

- Device RSSI

The receive signal strength from the end-user device is critical for putting the following metrics into the appropriate context. Low RSSI with other issues may be expected and does not necessarily indicate a poor network, but high RSSI with other issues indicates an issue that may be correctable or transient (e.g., interference).

These values are not calibrated and may be reported differently by different vendors, so specific device model behavior must be considered when incorporating into a calculation.

- AP Noise Floor (by band)

Another metric that is useful for context, noise floor is the amount of non-signal RF present. A low RSSI may be acceptable in an especially quiet environment.

- AP Tx MCS

This is the PHY rate the AP is using to transmit to the end-user device and it represents the best summary of all data available to the AP. MCS is the best single metric to indicate the quality of a network, as it's the direct result of every dynamic input previously captured.

- Device Tx MCS

Like AP Tx MCS above, this is the PHY rate the end-user device is using to transmit to the AP. This metric provides valuable insight into issues that may be occurring outside of the AP's ability to receive (e.g., hidden nodes, non-overlapping interference, etc.).

- Wi-Fi Latency / Jitter

While true end-to-end latency and jitter may be difficult to quantify, local statistics may be capturable. These markers can help indicate that certain use cases, such as voice or video calling, may be impacted even when combined with otherwise acceptable KPIs.

- Airtime utilization

Distinct from the network utilization metrics below, it is possible to saturate a wireless link without filling the backhaul network. Airtime utilization is a great way to evaluate if a WLAN is worth roaming to, as it combines factors such as MCS and frame retries.

- Frame retries

Usually included in any set of troubleshooting metrics, frame retries are a great way to understand how close you are to having a problem. A frame could be retried multiple times and yet still be successfully received. Retries, at sufficient rates, will affect MCS rates, and they serve as a good indicator of overall RF health. Note that AP Tx frame retry counts will be more accurate

than AP Rx counts – the AP knows every time it retries a frame but can only count the ones it successfully receives.

- Frame loss rate

Taking frame retries to the extreme, we have dropped frames. This should be weighted heavily, assuming frame losses due to end-user device roaming can be removed as expected and normal.

- Radio type

The capabilities of the AP and end-user device (e.g., 802.11b/n/ac/ax/be, spatial streams, channel widths, etc.) need to be factored into any quality equation, as a great 802.11n network may look like a bad 802.11ax network.

5. Future Direction

This first paper described the need for access network metrics and some proposed methods on what is important to capture to enable network evaluation. We anticipate continuing this work in two primary areas – analysis and communication.

5.1 Analysis

Gathering the KPIs referenced above will enable a variety of analyses that will provide meaningful insights into the relative quality of an access network. These analyses may happen locally in the AP, or in some core network entity. KPIs may be weighted differently, based on the use case (e.g., in a dense AP deployment, low RSSI may have a much greater impact). Additionally, other core metrics that are uniquely available to a single operator could be integrated into the final analysis. These may include upper layer IP performance, e.g., DNS response time, ping times, etc.

Regardless of these variances, a mutually understandable output must be achieved for effective cross-operator roaming decisions.

5.2 Communication

Communicating the KPIs referenced above will enable sharing these metrics with other stakeholders. A reliable way to communicate these KPIs will be important for allowing these stakeholders to make informed decisions on whether or not to use a particular network, or even allowing for consistent insight into one's own network. The next phase of this work should identify the stakeholders to share these KPIs with, as well as recommend methods for communicating that data.

A stakeholder could be an IDP or an ANP, as described in many of the Use Cases in Section 3 above. RADIUS is a protocol already used today in many authentication scenarios, and should be one

mechanism considered for communicating KPIs to an IDP or ANP. There are some AP vendors that send some metrics (such as throughput, radio type, RSSI, and channel) in RADIUS Access-Request packets today. However, this is not a currently widespread practice amongst AP vendors.

Another stakeholder could be the end-user device. Using ANQP (Access Network Query Protocol) and GAS (Generic Advertisement Service) could be one way to share these metrics from an AP to that end-user device. This could enable KPIs to be shared pre-association, allowing the Wi-Fi client to make more informed choices in areas such as connection steering.

Some vendors also use APIs to communicate KPIs out-of-band of the authentication itself. This is another possible mechanism that is less real-time than RADIUS or ANQP, but enables insight into a venue's QoE overtime which could then be used in real-time decisions, or feed into reports. Whereas these systems are vendor-proprietary today, there may be an opportunity for WBA to look to converge efforts under a "WRIX API" program.

Phase 2 of this group's work should consider all of these mechanisms, as well as any others that could enable reliable delivery of these KPIs.

5.3 Alignment with 5G

Phase 2 of this group's work should consider industry alignment in terms of how applications become aware of network QoS. More specifically, 3GPP has defined a Network Exposure Function (NEF) that permits an application function to be notified about analytics information of user data congestion, network performance, QoS sustainability and service experience information. The Phase 2 work can examine the possible re-use and/or adaptation of 3GPP NEF-based approaches to support the Wi-Fi use cases identified in section 3.

Table of Definitions and Acronyms

ANP	In the context of roaming (subscribers are able to gain access to a provider's network as part of a prior arrangement), the network connectivity provider is called the Access Network Provider (ANP).
ANQP	Access Network Query Protocol. Defined in IEEE Std 802.11, the query protocol for access network information retrieval, transported by generic advertisement service (GAS) Public Action frames
ePDG	Evolved Packet Data Gateway. A component of a 3GPP network that provides a UE access to the Evolved Packet Core over a non-3GPP access, typically Wi-Fi.
GAS	Generic Advertisement Service. Defined in IEEE Std 802.11 as an over-the-air transport for higher-layer advertisements between an advertisement server and end-user devices.
IDP	In the context of roaming (subscribers are able to gain access to a provider's network as part of a prior arrangement), the authenticating company who owns the end user / subscriber relationship is the 'Identity Provider (IDP).
MCS	Modulation and Coding Scheme. A specification of the physical layer (PHY) parameters that consists of modulation order and forward error correction (FEC) coding rate, and, depending on the context, the number of spacetime streams.
NEF	Network Exposure Function. A 3GPP standard node exposing network services and capabilities to applications.
NOC	Network Operations Center. A centralized location where computer, telecommunications or satellite networks systems are monitored and managed.
QoS	Quality of Service. Specific and/or detailed technical metrics for a network link or service. These metrics can be measured objectively and, in many situations, controlled through management systems. Note: In some contexts, "QoS" is used to refer specifically to Wi-Fi priority queues.
QoE	Quality of Experience. The perception of network service by its users. QoE can be subjective, or can be measured qualitatively through surveys and user feedback.
RADIUS	Remote Authentication Dial-In User Service. Defined in IETF RFC 2865, an Authorization, Authentication and Accounting (AAA) protocol to manage end-user access to network resources.
RSSI	Received Signal Strength Indicator. An estimated measurement of how well a device can hear, detect and receive signals from an Access Point. Some uses of "RSSI" are only a relative measure with no absolute value.
STB	Set Top Box. A customer-premise device that provides video services to a television.
XLA	Experience Level Agreement. An agreement or commitment for a level of end-user experience.

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