Qualcomm Dragonwing

Qualcomm Dragonwing™ Service Defined Wi-Fi

Delivering Exceptional User Experience

Qualcomm Technologies, Inc.
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Contents

1. Executive Summary

In today's digital age, Wi-Fi is more than just a convenience; it is a critical infrastructure that powers our homes, schools, and workplaces. As the reliance on wireless connectivity escalates, so do the expectations for speed, reliability, and seamless user experience. Traditional Wi-Fi networks, however, often struggle to keep up with the increasing demands of modern real-time applications, which require not only high bandwidth but also low latency and minimal jitter to deliver interactive and immersive experiences.

This white paper delves into the complexities of current Wi-Fi environments and the pressing need for networks that can adapt to varied and intensive usage scenarios. Through an in-depth exploration of Dragonwing Service Defined Wi-Fi, we will uncover how this technology enables service providers to leverage service orchestration, service-aware optimization, and service assurance to deliver exceptional performance and reliability. By examining various use cases—from dense, multi-client environments to enterprise productivity applications—this paper will demonstrate the transformative impact of our technology in meeting today's connectivity challenges and setting new standards for tomorrow's wireless experiences.

2. Background

2.1 Wi-Fi: The Backbone of Modern Connectivity and Performance

Wi-Fi has revolutionized connectivity in homes, businesses, and beyond. As Wi-Fi's predominance has reached every segment of society, the significance of its performance has also increased.

In the home, subscribers judge the quality of their broadband service and end devices based on their Wi-Fi experience. Similarly, in enterprise settings, where business-critical operations such as real-time data analytics and online transaction processing are increasingly reliant on Wi-Fi connectivity, the quality of the Wi-Fi network becomes paramount. Organizations depend on Wi-Fi for seamless communication, data transfer, and access to cloud-based applications. The performance of Wi-Fi networks directly affects productivity, efficiency, and overall business operations.

As end users' expectations and reliance on Wi-Fi services have soared, the demands placed on networks have experienced exponential growth, primarily driven by the rapid introduction of new devices and increasingly resource-intensive applications. This surge in demand presents substantial challenges to Wi-Fi's capabilities.

2.2 Beyond Speed: Meeting the Demands of Modern Applications

In today's digital environment, the strain on Wi-Fi networks is escalating due to the surge in latency-sensitive applications such as video conferencing and gaming, increased demands for bandwidth driven by streaming services, and the escalating number of connected devices. Applications like video collaboration, gaming, augmented reality (AR), and virtual reality (VR) are becoming more prevalent in sectors such as entertainment, education, and training.

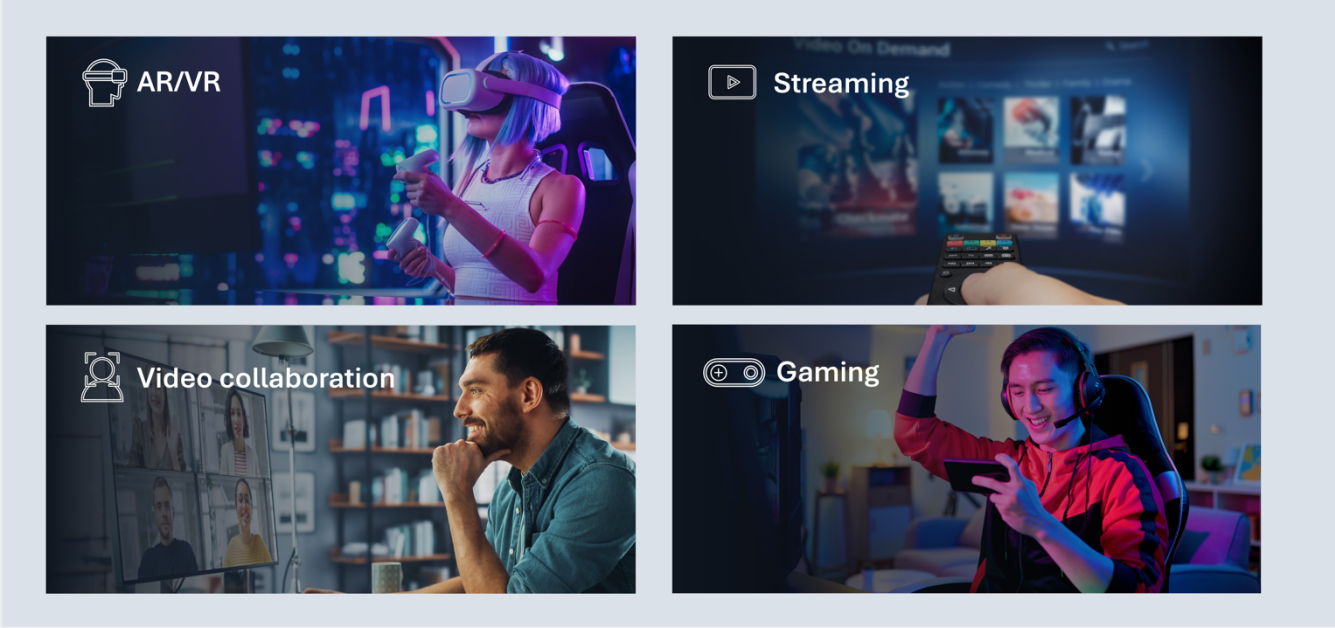

Figure 1: Interactive and Immersive Applications

As these technologies become more embedded in daily life and critical operations, the necessity for enhanced Wi-Fi capabilities becomes more apparent. This need is propelled by the demands of interactive and immersive applications, which require not only high bandwidth but also low latency and minimal jitter to ensure a high-quality user experience.

This growing reliance on advanced applications elevates the importance of Quality of Experience (QoE). User satisfaction now extends beyond merely measuring broadband speeds, focusing instead on the comprehensive performance of Wi-Fi networks as experienced by users through the applications that matter the most to them. This shift underscores the need for reliable Wi-Fi services that can accurately identify and meet the demands of real-time applications, thereby ensuring a seamless user experience.

2.3 The Impact of Latency and Jitter

Network latency is defined as the duration required for a data packet to travel from its source to its destination. Excessive network latency significantly impacts applications, as users may experience lag, freezing, or lack of interactivity in the content. Users often become aware of latency through network speed tests, which report ping times. However, these times reflect the total latency across all network segments—from the user's device to the ping server—including the Wi-Fi connection, access networks (e.g., cable, DSL, fiber), the core network, and the cloud servers' access network. The Wi-Fi network however is often the segment where latency becomes the most severe and unpredictable due to the shared nature of the air interface medium.

Even when modern broadband services provide substantial bandwidth, it does not inherently ensure low latency. As network traffic increases, data packets accumulate and get queued in routers, awaiting transmission over the air interface. This means that the latency achieved is highly dependent on the network load, the density of the deployment, and interference (e.g., from overlapping Wi-Fi networks).

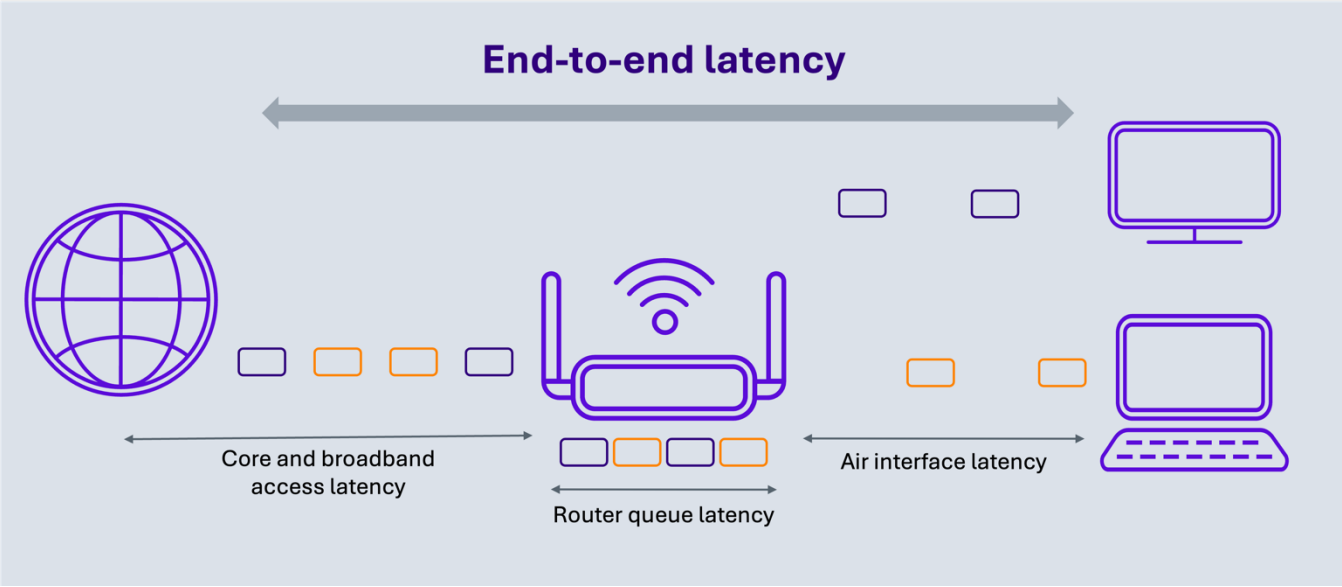

Figure 2: Network Latency

Another important concept determining networking performance is jitter; this is the variation in latencies experienced by data packets between two network nodes. A high-quality experience for real-time applications can only be retained if an exceedingly small percentage of packets arrive later than a specific deadline (delay bounding).

Latency and jitter are most acute during peak usage times when multiple users are simultaneously engaged in bandwidth-intensive and highly interactive applications (steaming, online gaming, etc.). Thus, managing these elements is crucial for service providers to ensure user satisfaction and maintain a high quality of experience.

2.4 The Complexity of the Wireless Environment

While service providers can manage core and access network resources effectively, extending this control to the subscriber's wireless local network introduces significant challenges. To ensure a high-quality experience for demanding applications, it is crucial for providers to extend their provisioning control to the Wi-Fi interface, ensuring that applications receive the necessary bandwidth, latency, and jitter management.

However, the non-deterministic, highly dynamic, and shared spectrum nature of Wi-Fi networks makes it difficult to ensure consistent performance. This challenge is compounded by factors such as the diversity and number of connected devices, the variety of applications in use, and even the physical layout of the environment. These elements create a dynamic environment where traffic, congestion, and interference can vary significantly.

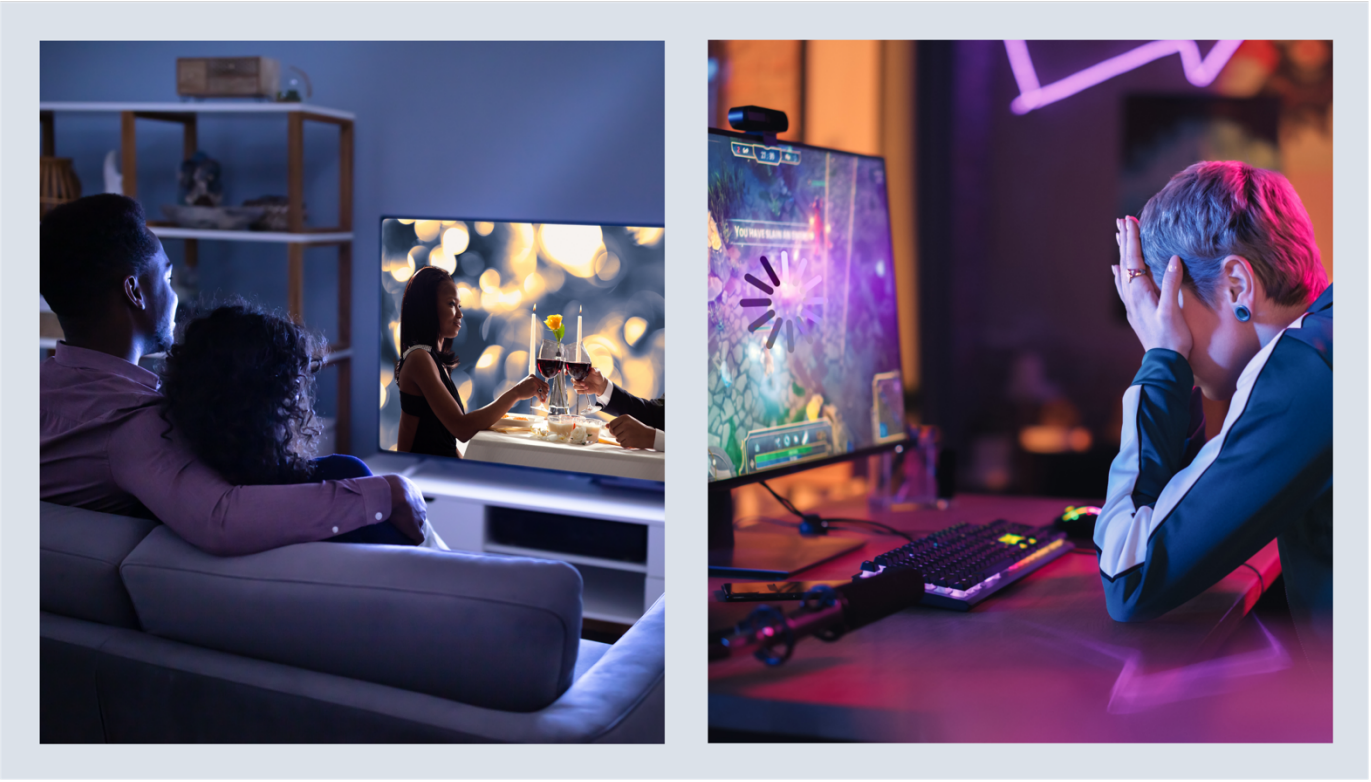

Figure 3: Application Quality of Experience

3. A New Era of Quality of Experience Management

The industry has long recognized the challenges associated with managing Wi-Fi experience and has attempted to address them.

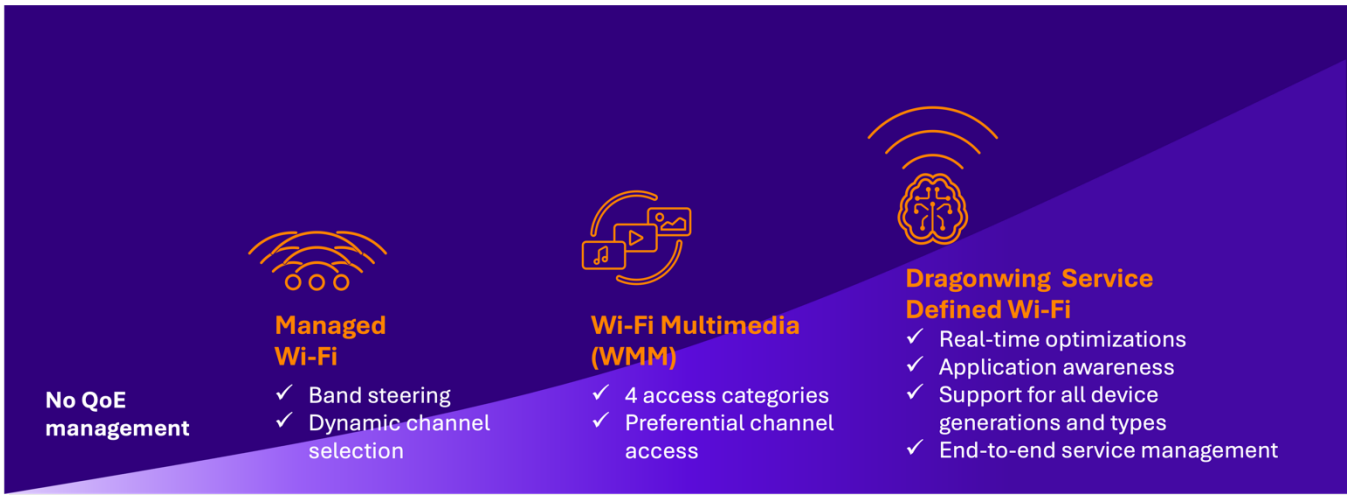

Figure 4: The Evolution of QoE Management

Today, methods to enhance in-home Wi-Fi connectivity include managed Wi-Fi solutions that mitigate interference and standards-based Quality of Service (QoS) initiatives like Wi-Fi Multimedia (WMM). While these tools improve the robustness of Wi-Fi networks, they primarily focus on external remediation of Wi-Fi issues. However, these approaches overlook the unique profiles of user applications and services, offering limited granularity in managing them.

Recent Wi-Fi standards incorporating features like Stream Classification Service (SCS), aim to overcome the WMM limitations. However, the lack of widespread adoption results in uneven user experiences across devices from different generations and types.

To address these limitations, Qualcomm Technologies has introduced Dragonwing Service Defined Wi-Fi technology, ushering in a new era of user experience management. This innovation enhances the Wi-Fi interface with application-level awareness and real-time traffic optimization. It empowers service providers to orchestrate their services end to end, allowing them to effectively manage their subscribers' quality of experiences and enables consistent experience quality across devices from different generations and types.

4. Dragonwing Service Defined Wi-Fi

Dragonwing Service Defined Wi-Fi is an innovative technology that enhances the Wi-Fi experience by intelligently optimizing network traffic. This technology operates on a cloud-to-device Quality of Experience (QoE) framework, which allows for precise control and optimization of Wi-Fi traffic in real time based on the type of applications being used. It is designed to prioritize traffic flows, reduce latency and jitter, and adapt to varying user demands and network conditions, ensuring optimal performance even in congested environments.

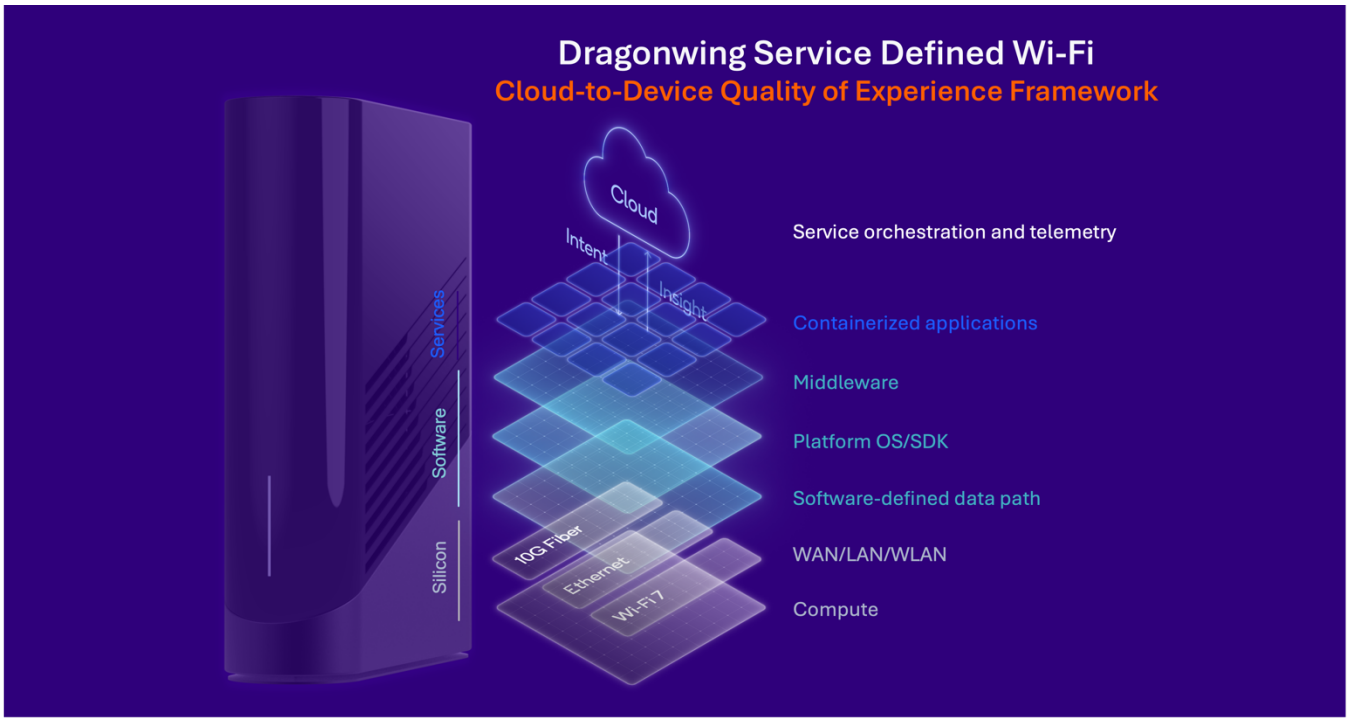

Figure 5: Cloud-to-Device Quality of Experience Framework

Dragonwing Service Defined Wi-Fi enables service orchestration to extend across the network from the cloud to the device. Additionally, telemetry enables insights into network health and user experience. This can enable service providers to proactively manage the service quality delivered to end users. The technology is designed to meet the needs of modern applications like streaming, online gaming, and video conferencing, providing a seamless and superior user experience.

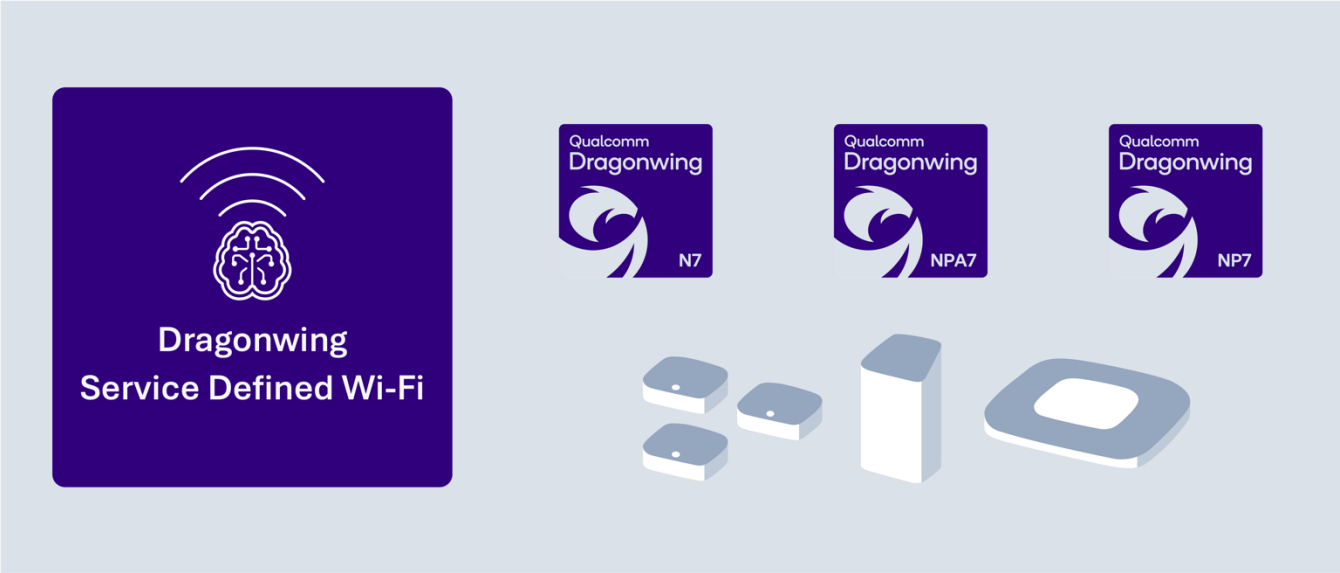

Figure 6: Portfolio of Wi-Fi 7 Networking Platforms

Dragonwing Service Defined Wi-Fi is supported across Qualcomm Technologies' full portfolio of Wi-Fi 7 networking platforms.

Qualcomm Technologies' advanced Wi-Fi 7 networking platforms support solutions ranging from home mesh systems to high-performance broadband gateways and massive-capacity Access Points for enterprise and public venues.

- Dragonwing™ NPro Platforms combine superior connectivity, computing power, and intelligence. These high-performance enterprise solutions keep users connected, with platform options that can peak at a system capacity of 33 Gbps designed to deliver high-bandwidth connectivity in businesses, schools, and venues with hundreds or thousands of simultaneous users.
- Dragonwing™ N Platforms enable compact, power-efficient, and cost-effective designs with a modular and scalable architecture to deliver a premium Wi-Fi user experience for virtually every size home and small business—powerful enough to support highly demanding networks with innovative mesh Wi-Fi capabilities and Wi-Fi 7 connectivity.

5. Dragonwing Service Defined Wi-Fi Technology Pillars

This technology integrates three fundamental components: service orchestration, service-aware optimization, and service assurance, each playing a crucial role in managing and improving the quality of Wi-Fi networks.

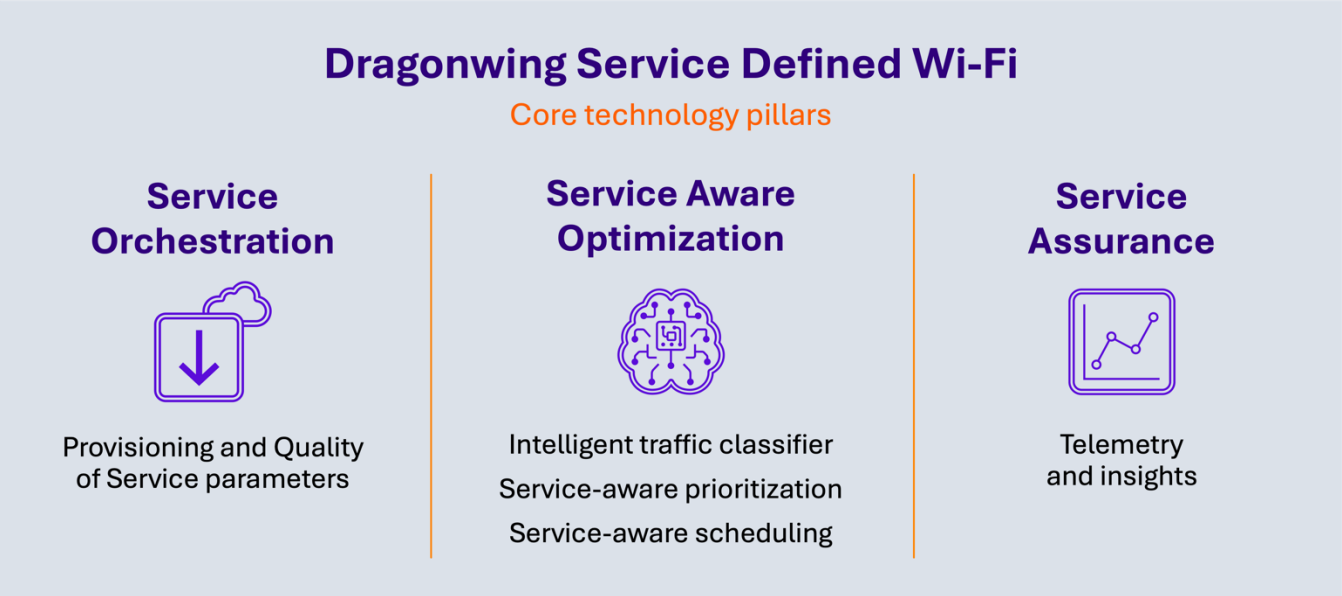

Figure 7: Dragonwing Service Defined Wi-Fi Core Technology Pillars

5.1 Service Orchestration

Dragonwing Service Defined Wi-Fi provides an open API framework that streamlines the provisioning of the Wi-Fi router by abstracting the complexity of service management.

The Dragonwing Service Defined Wi-Fi API framework can enable:

- **Service Tiering and Service Level Agreement (SLA) Control**: A wide range of user-defined service classes, each associated to specific Service Level Agreements. This flexibility allows service providers to configure various service tiers—for example for gaming or work-from-home, each customized for unique user needs or applications such as video collaboration, virtual reality, gaming, and more.
- **Granular Quality of Service (QoS) Configuration**: Precise control over QoS parameters. This includes setting thresholds for throughput, latency bounding, burst size, priority, loss and more, enabling fine-tuning of service delivery in relation to the demands of each application.
- **Dynamic Traffic Flow Mapping**: Service classes to dynamically map traffic flows to their service tiers, ensuring each flow receives the desired QoS treatment needed to optimize applications delivery.
- **End-to-end Service Policy Integration**: Consistent application of service policies across wired and wireless networks by mapping WAN/Ethernet QoS parameters into WLAN interfaces. This creates a unified policy framework for consistent end-to-end traffic treatment across different network types.
- **Stream Classification Service (SCS) Support:** Application of QoS treatment for traffic flows in response to client requests.

- **Bi-directional Flow Management**: Bi-directional traffic management within the Wi-Fi router—downlink (on the ingress from the broadband interface to Wi-Fi clients) and uplink (on the egress from Wi-Fi clients towards the broadband's upstream). This approach is designed to ensure consistent performance even when there is a capacity imbalance between these interfaces.

5.2 Service Aware Optimization

Through real-time traffic flow classification and dynamic prioritization, Dragonwing Service Defined Wi-Fi technology ensures that applications receive the network resources they need to perform optimally, even in congested network conditions.

Dragonwing Service Defined Wi-Fi uses the following components:

- **Smart Traffic Classifier:** The technology uses an advanced traffic classifier to identify applications in real time by analyzing traffic flows. It effectively recognizes active application categories such as gaming, video collaboration, voice communications, and more without relying on Deep Packet Inspection.
- **Service Aware Prioritization:** Once applications are identified, traffic flows are dynamically prioritized according to their service class. This method ensures that the most critical applications for the user receive the highest priority.
- **Traffic Scheduling:** Dragonwing Service Defined Wi-Fi manages the data path and queuing to ensure that each application type (gaming, voice, video, XR, etc.) receives the specific QoS treatment required for optimal delivery.
- **Radio Resource Management:** This process dynamically allocates radio resources and manages radio transmission modes to address air interface congestion, traffic load, and client devices performance. It enables real-time adjustments based on application requirements, congestion profiles, and the capabilities of different generations of client devices, automatically optimizing to maintain the quality of the application experience.

5.3 Service Assurance

The Dragonwing Service Defined Wi-Fi framework offers a comprehensive suite of telemetry tools, empowering service providers with deep insights into network health and performance. This enables their technical teams to access actionable data, facilitating proactive resolution of performance issues.

Dragonwing Service Defined Wi-Fi framework provides:

- **Telemetry API:** Exposure of an extensive set of metrics, providing deep visibility into the subscriber's local network down to individual devices.
- **Granular Performance Metrics:** Performance metrics on a per-peer and per-service class basis.
- **Real-Time Monitoring of Channel Load and Interference:** Visibility into the network's health with channel load and interference.
- **QoE Monitoring:** Per-service SLA monitoring, enabling service providers to assess how each service instance performs relative to the expected parameters of its service class for deep insight into their subscribers' QoE.

6. The Impact of Dragonwing Service Defined Wi-Fi

In the following sections, we will explore common scenarios that showcase the real-life impact of Dragonwing Service Defined Wi-Fi in improving QoE by reducing latency and jitter.

The analyses were performed across a set of intense-usage network deployments spanning home, enterprise, and gaming scenarios. The interference profiles presented in these scenarios illustrate network congestion caused by multiple devices simultaneously connected to a single Access Point—a common occurrence in modern homes and enterprises—as well as overlapping network environments (OBSS), typical in densely-populated apartment buildings and offices.

In each scenario, Dragonwing Service Defined Wi-Fi technology is deployed on a Wi-Fi 7 Dragonwing NPro 7 based Access Point. Legacy Wi-Fi client devices connect to this Access Point, and test traffic is generated using a traffic generator. The latency measurements and associated analysis contrast the effects of Dragonwing Service Defined Wi-Fi on traffic flows with those where Dragonwing Service Defined Wi-Fi is not enabled.

6.1 Dense Multi-Client Multi-Application Use Case

Wi-Fi network environments have grown increasingly complex, with a multitude of devices connected to the same network, each serving diverse purposes like conference calls, gaming, video streaming, and remote work—real-time applications reliant on network resources for optimal performance. As such, one of the primary scenarios is a dense, multi-client, multi-application Wi-Fi network scenario.

6.1.1 Test Description

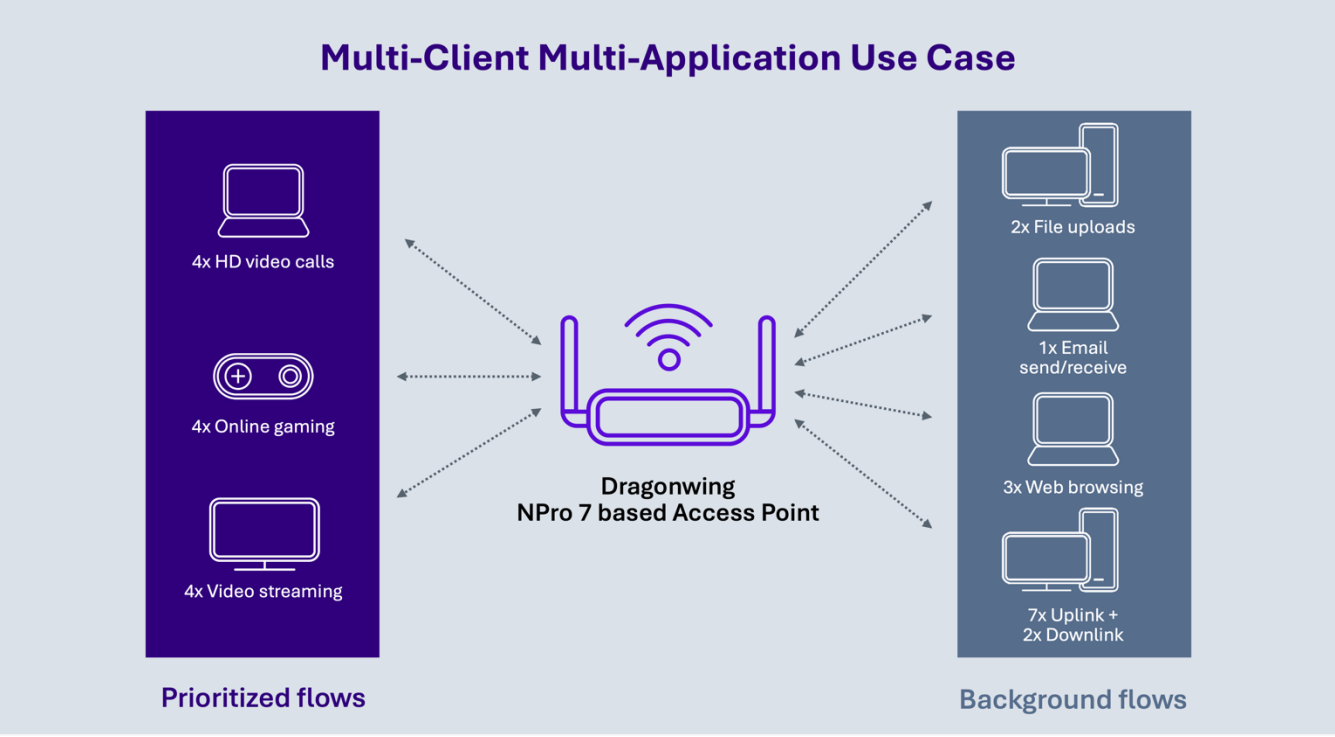

Figure 8: Multi-Client Multi-Application Test Configuration

The setup consisted of the following set of users, applications, and traffic patterns:

Dragonwing Service Defined Wi-Fi Prioritized traffic flows:

- 4x High-definition video calls (3 Mbps each, bi-directional)
- 4x Multiplayer online gaming sessions (1.5 Mbps each, bi-directional)
- 4x Video streaming (1.5 Mbps each, downlink)

Background traffic flows on the same Wi-Fi network:

- 2x File uploads (10 Mbps each, uplink)
- 1x Email send/receive
- 3x Interactive web browsing sessions
- 7x Background traffic clients (1344 Mbps each, uplink)
- 2x Background traffic clients (50 Mbps each, downlink)

6.1.2 Latency Measurements

The following figure displays the average and 95th percentile round-trip latency of data flows through the Wi-Fi Access Point, comparing data sets with Dragonwing Service Defined Wi-Fi enabled and disabled. Flows prioritized with Dragonwing Service Defined Wi-Fi experience up to 50% in average latency reduction.

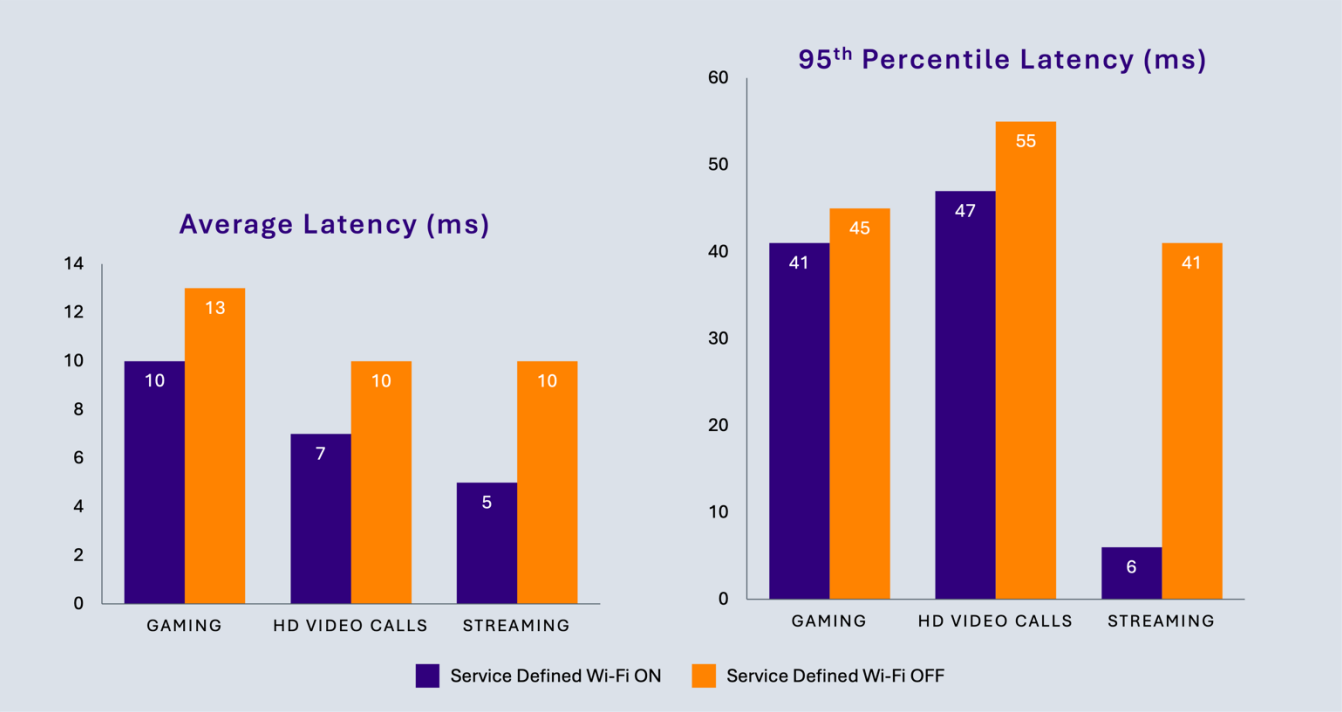

Figure 9: Latency (Average and 95th Percentile) for Multi-Client Multi-Application Use Case

6.1.3 Jitter Measurements

The following figure displays the maximum jitter of data flows through the Wi-Fi Access Point, comparing data sets with Dragonwing Service Defined Wi-Fi enabled and disabled. Flows prioritized with Dragonwing Service Defined Wi-Fi experience up to 56% in maximum jitter reduction.

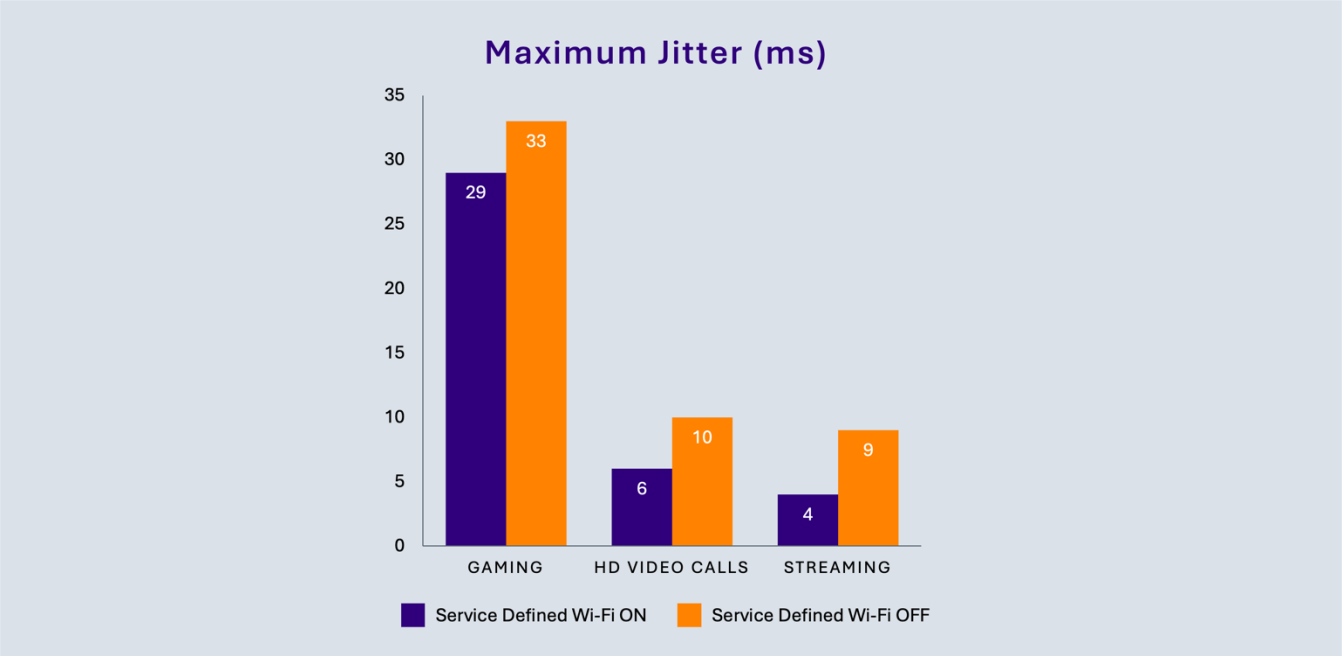

Figure 10: Jitter (Maximum) for Multi-Client Multi-Application Use Case

6.2 Classroom Use Case

With most educational resources and activities now integrating digital components, reliable and consistent Wi-Fi is crucial in classrooms. This ensures that tasks such as streaming educational videos, using cloud-based learning management systems, and engaging in real-time interactive classroom activities can operate smoothly without disruptions like buffering or disconnections. Such reliability is key to keeping students engaged and actively participating. The following use case showcases how Dragonwing Service Defined Wi-Fi is used to maintain seamless connectivity in a 20-person classroom scenario where digital resources are accessed simultaneously.

6.2.1 Test Description

For this use case, the analysis included a configuration with 20 users accessing digital resources, while background traffic is generated within the same network.

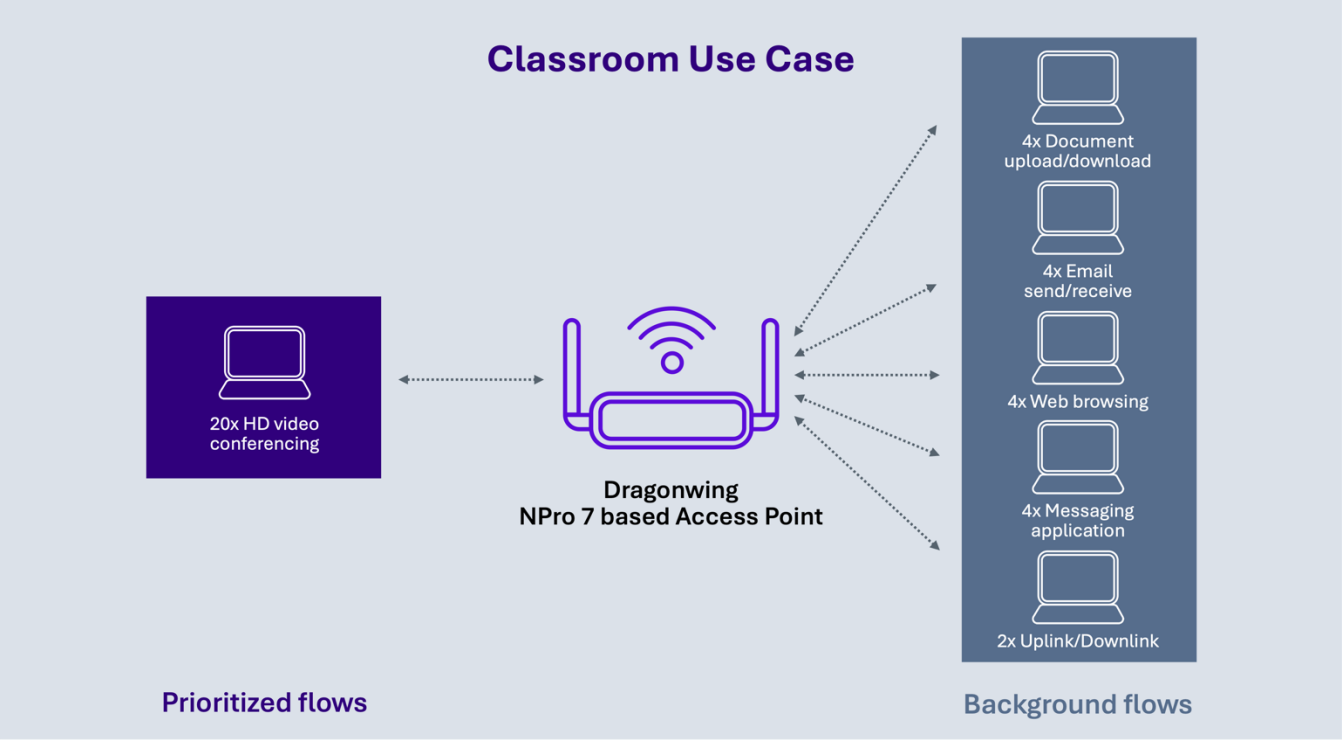

Figure 11: Classroom Test Configuration

The setup consisted of the following set of users, applications, and traffic patterns:

Dragonwing Service Defined Wi-Fi Prioritized traffic flows:

- 20x High-definition video conferencing (3 Mbps each, bi-directional)

Background traffic flows on overlapping Wi-Fi network:

- 4x Email send/receive
- 4x Web browsing
- 4x Messaging application
- 2x Background traffic clients (full buffer, uplink)
- 2x Background traffic clients (full buffer, downlink)
- 4x Document uploads/downloads (3 Mbps each, bi-directional)

6.2.2 Latency Measurements

The following figure displays the average and 95th percentile round-trip latency of data flows through the Wi-Fi Access Point, comparing data sets with Dragonwing Service Defined Wi-Fi enabled and disabled. Flows prioritized with Dragonwing Service Defined Wi-Fi experience up to 41% in average latency reduction.

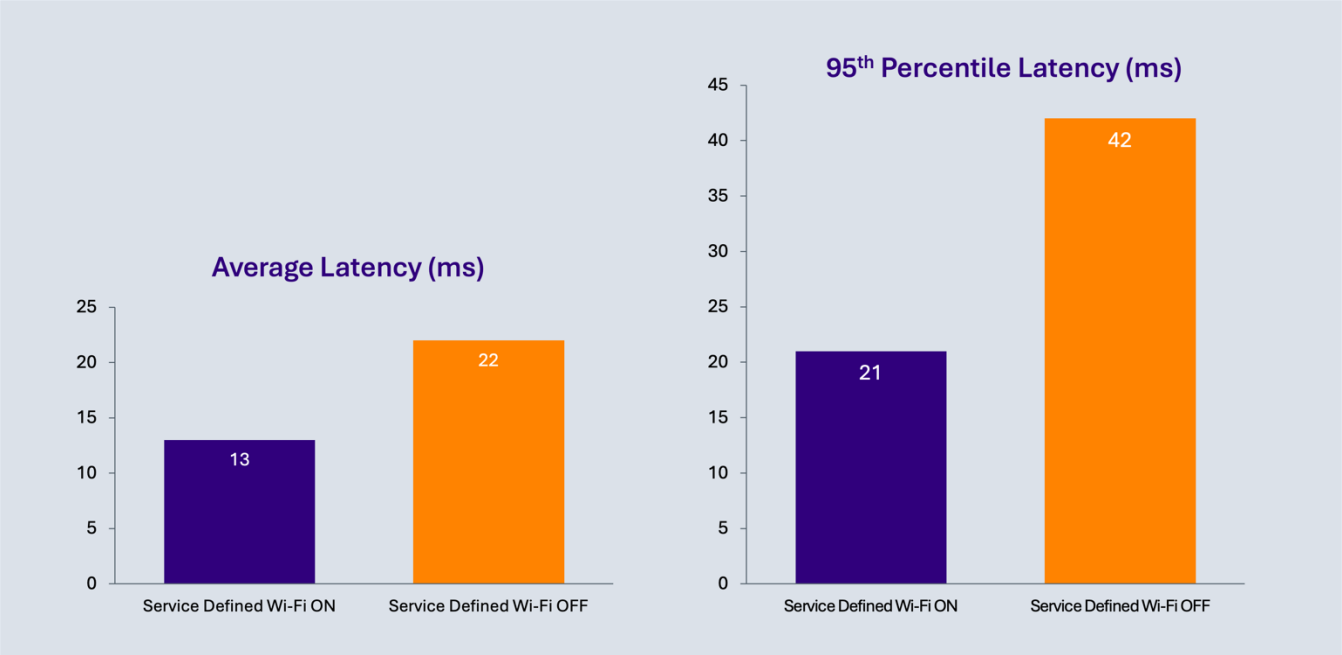

Figure 12: Latency (Average and 95th Percentile) for Classroom Use Case

6.2.3 Jitter Measurements

The following figure displays the maximum jitter of prioritized data flows through the Wi-Fi Access Point, comparing data sets with Dragonwing Service Defined Wi-Fi enabled and disabled. Flows prioritized with Dragonwing Service Defined Wi-Fi experience up to 20% in maximum jitter reduction.

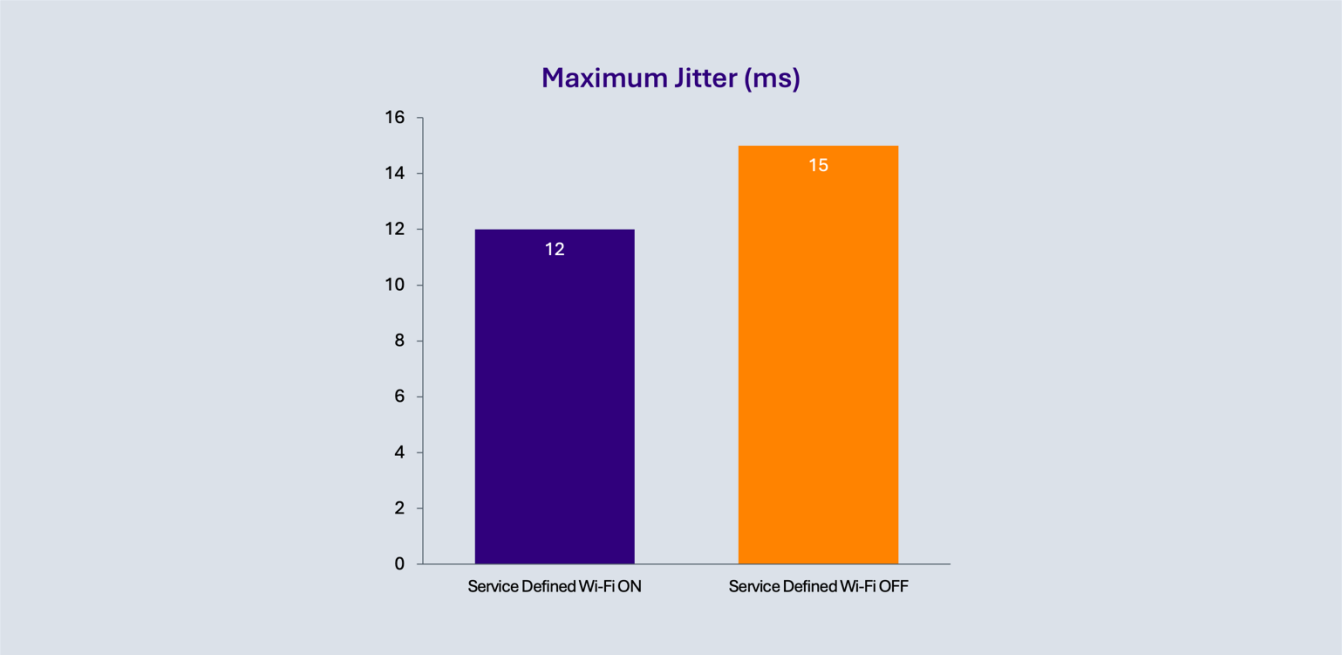

Figure 13: Jitter (Maximum) for Classroom Use Case

6.3 Gaming Use Case

Gaming is one of the most demanding applications for Wi-Fi connectivity, as even slight delays between a player's action and the game's response can be the difference between winning and losing. Gamers rely on Ping Latency as the essential metric to monitor lag throughout their gameplay. The following use case showcases how Dragonwing Service Defined Wi-Fi is used to maintain Ping latency when prioritizing gaming traffic in a congested network environment.

6.3.1 Test Description

For this scenario, the analysis tracks the Ping performance of a gaming session conducted on a gaming console. This network also supports other clients connected to the same Access Point, which collectively generate 80% channel load.

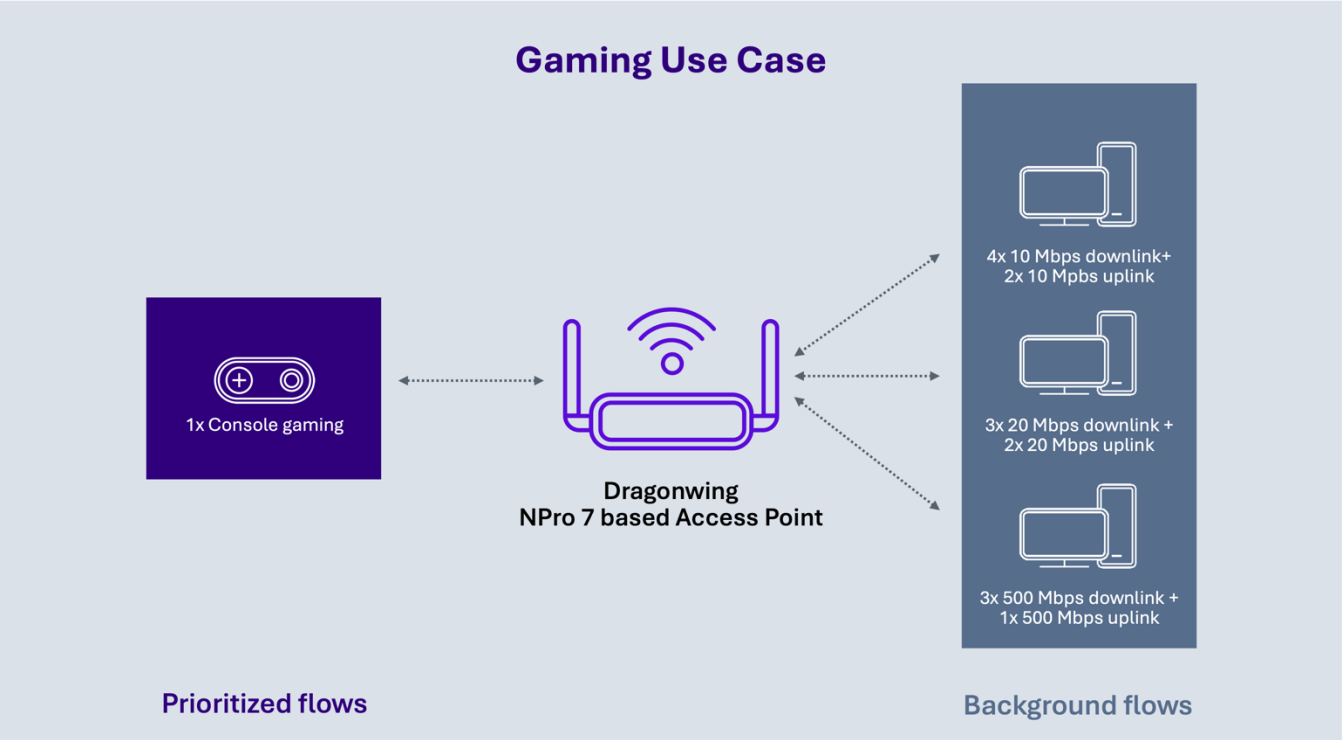

Figure 14: Gaming Test Configuration

The setup consisted of the following set of users, applications, and traffic patterns:

Dragonwing Service Defined Wi-Fi Prioritized traffic flows:

- 1x Gaming Console

Background traffic flows on the same Wi-Fi network:

- 4x Clients (10 Mbps each, downlink)
- 2x Clients (10 Mbps each, uplink)
- 3x Clients (20 Mbps each, downlink)
- 2x Clients (20 Mbps each, uplink)

- 3x Clients (500 Mbps each, downlink)
- 1x Clients (500 Mbps each, uplink)

6.3.2 Latency Measurements Console Gaming

The following figure illustrates the minimum and maximum Ping latency for console gaming in the presence of 80% channel load, comparing data sets with Dragonwing Service Defined Wi-Fi enabled and disabled. With Dragonwing Service Defined Wi-Fi, the maximum Ping latency is reduced by 29%.

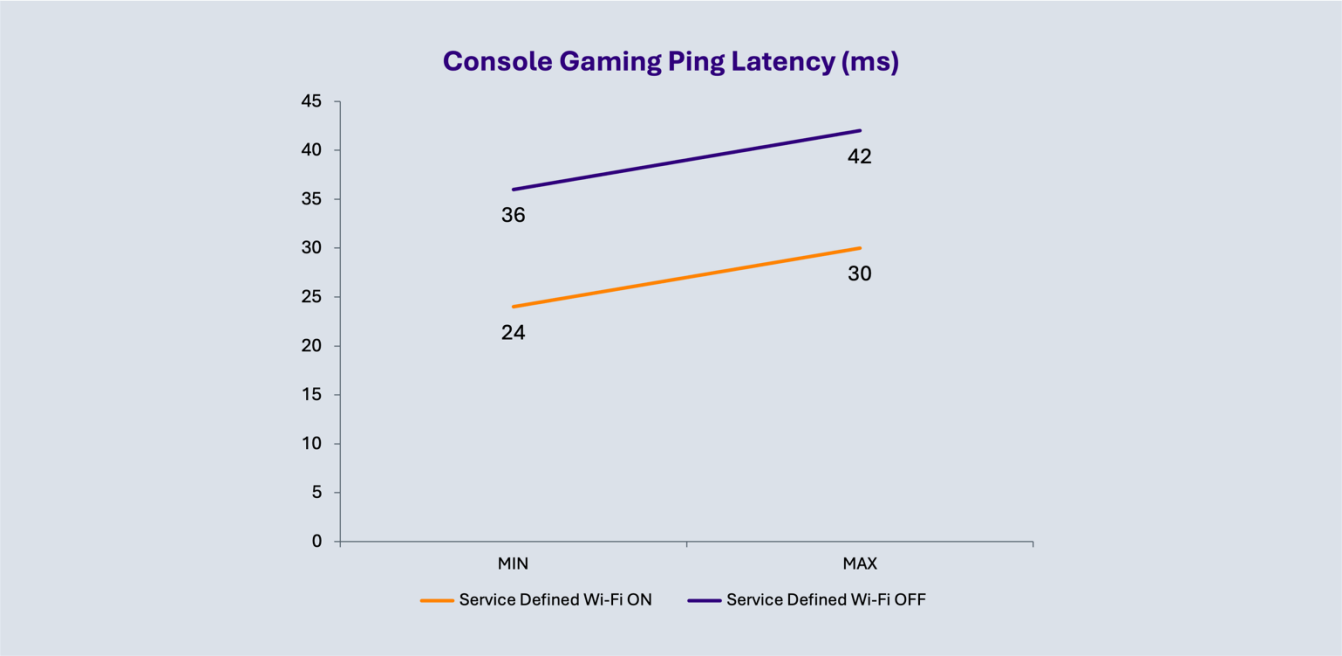

Figure 15: Ping Latency (Min and Max) for Console Gaming Use Case

6.4 Enterprise Productivity Voice and Video Use Case

Real-time communication is the cornerstone of modern enterprise settings, where users frequently engage in bi-directional communication applications, such as video conferencing and VoIP services, across a diverse array of devices connected to the network. These applications require stable and robust Wi-Fi connectivity to function effectively without issues like pixelation, lag, or garbled voices, which can disrupt meetings and affect productivity. The following use case showcases how Dragonwing Service Defined Wi-Fi plays a pivotal role in ensuring robust service delivery and higher quality experiences with the latency-sensitive applications prevalent in office environments.

6.4.1 Test Description

For this use case, the analysis included a configuration with 20 users using a VoIP application connected on the same Access Point while full buffer background traffic is generated by client devices. Subsequently the test is repeated with 20 users simultaneously using video applications.

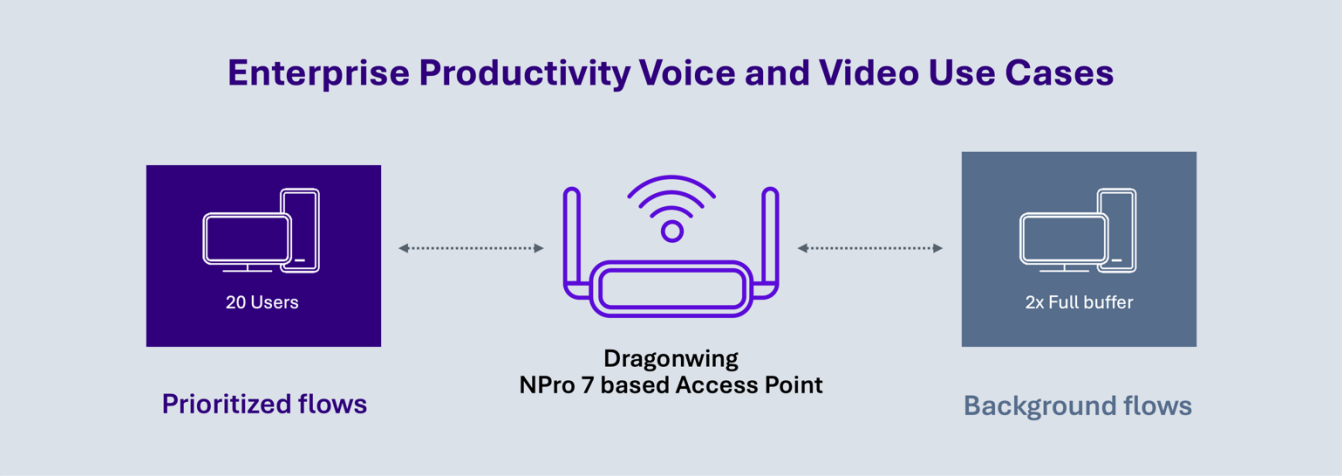

Figure 16: Enterprise Productivity Test Configuration

The setup consisted of the following set of users, applications, and traffic patterns:

Dragonwing Service Defined Wi-Fi Prioritized traffic flows:

- 20x VoIP users (bi-directional)
- 20x Video conferencing (uplink)

Background traffic flows on overlapping Wi-Fi network:

- 2x Clients (full buffer traffic, bi-directional)

6.4.2 VoIP Users Latency Measurements

The following figure displays the average round-trip latency of VoIP data flows through the Wi-Fi Access Point, comparing data sets with Dragonwing Service Defined Wi-Fi enabled and disabled. Flows prioritized with Dragonwing Service Defined Wi-Fi experience up to 72% average latency reduction for 20 simultaneous users.

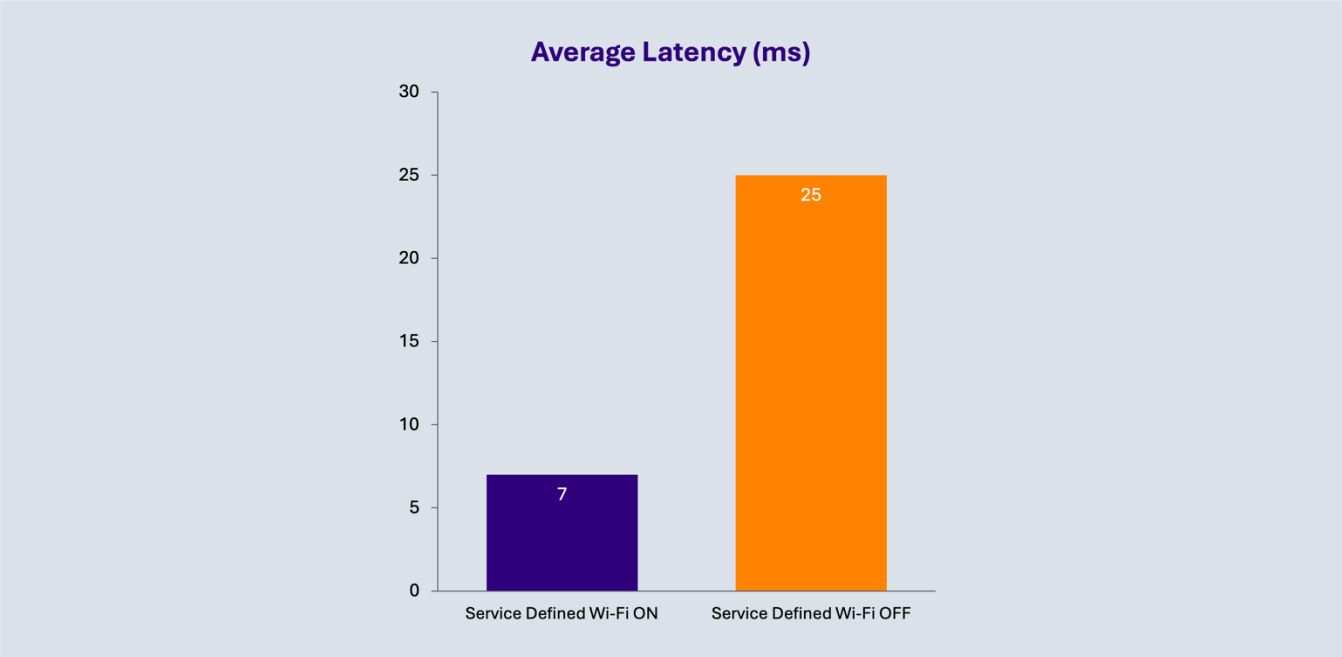

Figure 17: VoIP Latency (Average) for Enterprise Productivity Use Case

6.4.3 Video Users Latency Measurements

The following figure displays the average round-trip latency of video data flows through the Wi-Fi Access Point, comparing data sets with Dragonwing Service Defined Wi-Fi enabled and disabled. Flows prioritized with Dragonwing Service Defined Wi-Fi experience up to 30% average latency reduction for 20 simultaneous users.

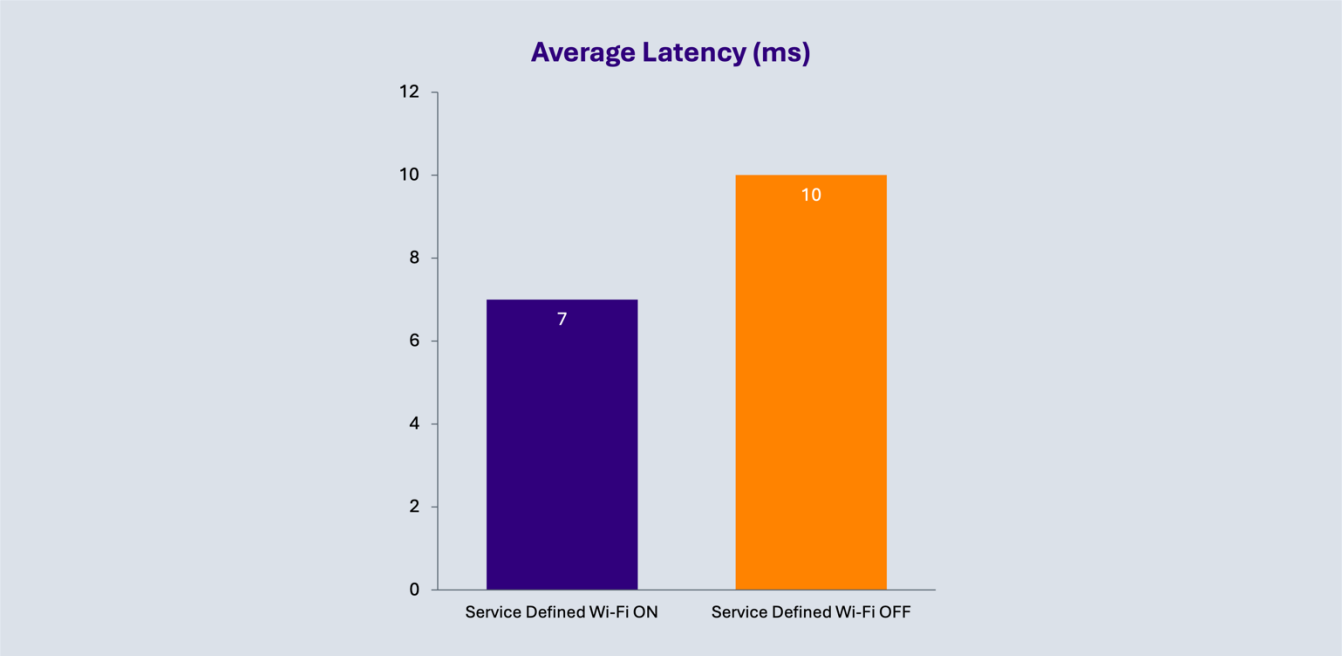

Figure 18: Video Latency (Average) for Enterprise Productivity Use Case

7. Conclusion

Dragonwing Service Defined Wi-Fi represents a significant advancement in wireless technology, addressing the evolving demands of modern connectivity with innovative solutions that enhance QoE for all users. By bringing application-level awareness and real-time traffic optimization to the Wi-Fi interface, this technology ensures that Wi-Fi networks are not only fast and reliable but also smart and adaptable to the diverse needs of various applications and environments.

Multiple use cases have demonstrated how Dragonwing Service Defined Wi-Fi technology offers significant benefits for both home and enterprise environments by enhancing the Wi-Fi experience through intelligent network traffic optimization:

- In home settings, this technology supports a variety of demanding network scenarios, such as simultaneous high-definition video calls, online gaming, and extensive device connectivity. It ensures that each application receives the necessary bandwidth and prioritization, reducing latency and jitter significantly, which is crucial for applications like streaming and gaming that require stable and fast internet connections.
- For enterprise environments, Dragonwing Service Defined Wi-Fi is particularly beneficial in managing the connectivity needs of a large number of simultaneous users engaging in bandwidth-intensive applications such as video conferencing and cloud-based services. The technology's ability to prioritize traffic flows and manage network resources effectively ensures that business-critical applications can receive the necessary network performance, thus enhancing productivity and efficiency. The advanced features of Qualcomm Technologies' Wi-Fi technology, such as service orchestration and real-time traffic optimization, allow for a seamless and consistent user experience across various devices and applications, which is vital in dynamic and demanding enterprise settings.

As we look to the future, the role of Wi-Fi will only grow more central in our lives and businesses. With the introduction of Dragonwing Service Defined Wi-Fi, service providers are equipped with the tools needed to deliver superior wireless experiences that meet the expectations of today's users and pave the way for tomorrow's innovations.

Qualcomm Dragonwing

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