Wi-Fi Spectrum Slicing:

A revolutionary approach to exceptional Wi-Fi performance

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Edgewater Wireless Systems Inc.
408 Churchill Ave., North, Ottawa, ON K1Z 5C6 CANADA **T** +1 613 271 3710
www.edgewaterwireless.com
www.aera.io

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Executive Summary

Wi-Fi growth has been staggering.

From smartphones and tablets to TVs and lightbulbs, there are over **8 billion Wi-Fi devices** in use today -- 3-billion of those devices were added over the last 12-months.

Explosive growth undeniably created a capacity crunch.

Wi-Fi now accounts for **40%** of customer care calls at Tier 1 MSOs and telcos. The cost burden generated by customer care calls and truck-rolls is enormous and only grows with each device added. Patched together software solutions on legacy platforms simply aren't fixing the problem.

Are we running out of spectrum?

Wi-Fi Spectrum Slicing is the answer – a revolutionary approach to exceptional Wi-Fi performance – packing more radios in a given coverage area while dramatically reducing contention and latency. Eliminating costly truck rolls and endless support costs, Wi-Fi Spectrum Slicing creates a scalable platform for revenue generation.

The industry leader in Wi-Fi Spectrum Slicing, Edgewater Wireless' groundbreaking solutions – from chipsets to licensing -- are proven in major enterprises and service providers – Mediacom, Kroger Corporation, Nokia and Comcast -- and are generating industry accolades from CableLabs UpRamp to the Wireless Broadband Alliance and the IEEE.

Targeting the multi-billion dollar Wi-Fi Access Point and Device markets, Edgewater's patented MCSR™ silicon solutions and, for large scale Silicon Companies, IP Licensing, offer a proven path to the next generation of Wi-Fi – today.

"40% of our customer care calls are Wi-Fi related" – SVP at US MSO

"AC (Wi-Fi5) was supposed to solve density and interference issues. Why can't we run more than a 20 MHz wide channel? Wi-Fi 6 doesn't solve the issue either." -- Wi-Fi engineer

"We're planning for 40-60 devices in the home, how can Wi-Fi deal with the capacity crunch?" – VP Customer Care at European MSO

The Wi-Fi Market

According to the Wireless Broadband Alliance (WBA), there are 8 billion Wi-Fi devices in use today, and, over the last 12-months, 3 billion new Wi-Fi devices were added[1]. Wi-Fi is ubiquitous, connecting everything from smartphones, iPads, and laptops to a growing number of other devices like cameras, thermostats, and even lightbulbs. By 2021, the WBA forecasts the market will reach 3.5 devices and connections per capita.

The explosive growth of high-data demand devices, such as smartphones, laptops and gaming platforms, is driving the $33 Billion global Wi-Fi market[2] toward higher user density demanding lower latency connections. The average North American user has over 3.64 Wi-Fi enabled devices[3] and is constantly accessing VoIP, HD video and other data-hungry apps such as SnapChat, YouTube, Facebook, and Netflix.

Wi-Fi now accounts for 40% of customer care calls.

Services providers -- from Telcos, cable operators to enterprises and in the home -- are struggling to deliver Wi-Fi networks capable of supporting these demanding applications. Also, Wi-Fi networks face the growing demand of the IoT, the wireless connectivity of typical household and office devices. Leading cable operators are preparing for home environments with 40-60 wireless-enabled devices

Virtually every wireless industry expert indicates that the high-density and interference problems will continue to plague wireless networks for years.

Something has to change.

[1] Monica Paolini, WBA Annual Industry Report 2019, Wireless Broadband Alliance (Source: https://www.wballiance.com/resource/wba-annual-industry-report-2019/) [October 2018]
[2] Source: http://www.marketsandmarkets.com/PressReleases/global-WiFi.asp
[3] Source: https://blog.globalwebindex.net/chart-of-the-day/digital-consumers-own-3-64-connected-devices/

Traditional Wi-Fi Architecture: Since 1999

Since the inception of Wi-Fi 1999, Wi-F has relied on the same approach based on a single-channel radio architecture.

This legacy, single-channel radio architecture, was not designed to withstand the challenges of the modern wireless world and has created an environment ripe for disruption. Wi-Fi Access point manufacturers have tried to overcome the issues by adding more single-channel radios within the same Wi-Fi access point. Still, the inability to mitigate interference degrades performance. Implementation is limited to between bands (i.e. 2.4 and 5 GHz) or at the widest reaches of the 5 GHz band using expensive componentry such has filters and diplexers.

Why? Let's take a more detailed view of the legacy approach.

As the market dynamic rapidly evolved to one of higher client and access point density, the IEEE standard has attempted to use wider channels to push more data in a shorter time. The baseline, single-channel radio architecture has been unchanged.

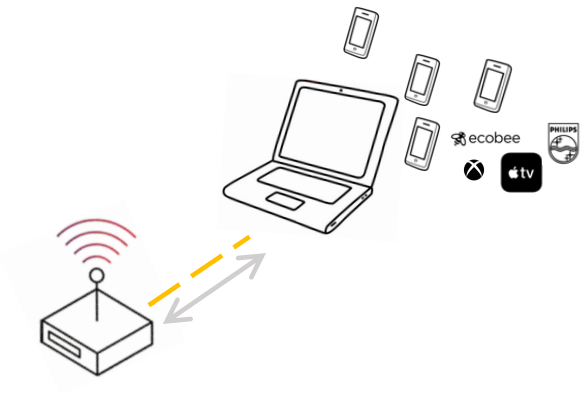

Figure 1: Legacy Wi-Fi offers a single channel, shared by all devices

Standards, from 802.11 N to AC and AX, have evolved with a focus on speed – specifically, burst rate speed – and use increasingly complex techniques, that have a net-negative impact on performance in high-client, open-air environments. Techniques such as:

- ***MIMO (Multiple Input Multiple Output)*** — the use of multiple spatial streams. Effective only at short ranges due to regulatory guidelines dividing power output by the number of antennae, MIMO also requires MIMO to MIMO to optimize gains (i.e. from 3x3 AP to a 3x3 device) – meaning it works best to bulky laptops vs smartphones etc. The primary end-user devices in any high-density environment and the home are handsets, tablets and IoT devices, which are SISO and, as a result, offer only one spatial stream, thereby negating many of the tangible benefits of MIMO.

- ***Wider channels*** — 40 MHz channel via combining two adjacent 20 MHz OFDM channels, or in the case of 802.11AC and 802.11AX, combining two 40 MHz channels or even two adjacent 80 MHz wide channels for 802.11AX. Effective only at a short-range due to regulatory limitations, wide channels severely limit reuse and are impacted by the adjacent channel availability problem (more interference = fewer adjacent channels available). Additionally, in 5 GHz, DFS requirements limit available adjacent channels and EU regulations limit power levels.

- ***Beam-forming*** — in high client density applications, transmit beam-forming behaves like an omni-directional antenna, radiating Tx power in all directions and capturing interference from all directions on Rx. In high-density applications, the benefits of beam-forming are negated.

- ***Increased QAM Rates*** – the shift from 802.11N to 802.11AC saw QAM rates increase from 64-QAM to 256-QAM. While the increased QAM rate allows more information to be packed into a waveform, it is usable in only very controlled conditions with limited or no interference as it is easily disrupted by

noise and requires a clear line of sight. Outside a faraday chamber or greenfield, the benefits are very rarely seen.

- *MU-MIMO* — downlink MU-MIMO is of questionable net benefit in high client and high access point density environments. The benefits are mainly limited downlink only (i.e. Access Point to a client) and require a homogeneous client environment.

As a result, in real-world high-density environments, the benefits of "burst-rate" focused implementations are quickly lost as the radio is forced to 'back off" to narrower and narrower channels — quickly resulting in 20 MHz channels.

At the core of the issue, the 802.11 spectral masks have wide side lobes making it challenging to run even non-overlapping channels in close proximity. The issue becomes more profound in areas of high access point density. In homes or enterprises with multi-access point/repeaters deployed nearby, side lobes create Adjacent Channel Interference (ACI), which swamps out Rx channels. Network performance suffers. In many cases, nearby access points are unable to pass traffic until transmitting is finished.

The common approach to Wi-Fi, as implemented by Qualcomm, Broadcom, Quantanna and Celeno, is still based on the legacy single-channel radio architecture. With the proliferation of wireless devices, traditional, *wireless network densification* is the biggest challenge facing network operators — and the legacy, single-channel Wi-Fi architecture has reached the end of its product lifecycle.

Capacity will remain the most significant issue for Wi-Fi. Ultimately, this has to be resolved.

IEEE 802.11 AC: Effects of channel bonding on spectrum utilization in dense environments
Research paper shows 160 MHz channels limited to 51 Mbps vs 8 x 20 MHz channels can offer 252 Mbps

Key findings from the IEEE paper include:
8 x 20 MHz channels may offer 252 Mbps compared to only 51 Mbps in a 160 MHz channel
It is more appropriate, in dense Wi-Fi environments, to separate the available WLANs into narrow channels in-order-to reduce collisions
A spectrum without channel bonding (only 20 MHz channels) may provide 500% the achieved throughput when using 160 MHz bonding
In dense WLAN deployments, many networks may need to share the same wide channel, leading to increased contention on the medium access, and hence increasing collision rate
When the number of Wi-Fi stations increases, all the 20 MHz channels become used, and their aggregated throughput exceeds that of the 160 MHz channel.
(Source: IEEE)

Solving the Capacity Crunch: What if?

What if we could support more devices in a coverage area? What if we could deliver the lower latency performance people crave for video, gaming and high-revenue applications? Are we running out of spectrum?

Why not completely change the Wi-Fi paradigm and slice the spectrum to unlock the potential to deliver exceptional Wi-Fi performance? Enter in-band Wi-Fi Spectrum Slicing.

What is Wi-Fi Spectrum Slicing?

In-band Wi-Fi Spectrum Slicing optimizes performance for all devices in a coverage area and allows spectrum to be sliced, allowing more radios to operate in a given area.

The challenge? Reduce interference so the radios can 'play nice' vs swamp one another out – the problem plaguing traditional Wi-Fi architecture.

A game-changing Wi-Fi innovation, *Wi-Fi Spectrum Slicing* can slice, for example, the 2.4 GHz ISM band, to support multiple concurrent channels within the same coverage area. Using a revolutionary implementation of standards compliant Wi-Fi, Wi-Fi Spectrum Slicing can deliver concurrent operation in multiple channels (i.e. 1,6,11). Mitigating the

performance degrading impacts of ACI and CCI, Wi-Fi Spectrum Slicing offers a paradigm shift to ***reducing contention*** and providing the highest quality-of-service to the most users possible.

Groundbreaking innovation: Edgewater Wireless

The first to market and industry leader in Wi-Fi Spectrum Slicing, Edgewater Wireless' has taken a dramatically different approach to Wi-Fi, developing groundbreaking solutions – from chipsets to licensing – designed to address the challenges of density and interference. Proven to reduce contention and improve performance in major enterprises and service providers, such as Mediacom, Kroger Corporation, Nokia and Comcast, and generating industry accolades from CableLabs UpRamp to the Wireless Broadband Alliance and the IEEE, Edgewater's patented MCSR™ silicon solutions and for global silicon companies, IP Licensing, offer a proven path to the next generation of Wi-Fi – today.

Edgewater's revolutionary MCSR™ silicon implements essential and patented interference techniques to lower the noise floor and allow multiple, concurrent channels of transmit and receive from as single radio – optimizing radio architecture for the real-world.

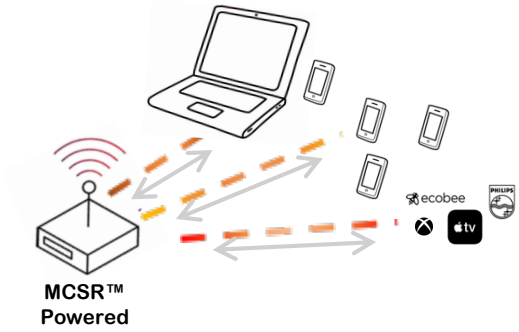

Figure 2: Wi-Fi Spectrum Slicing reduces contention & optimizes performance in the real-world

In with Wi-Fi spectrum, 2.4 GHz or 5 GHz, Edgewater's high-performance MCSR™ silicon captures a wide swath of the frequency band and, at the baseband level, uses a suite of patented techniques to extract multiple concurrent channels (radios) reducing contention and dramatically improving performance --- while adhering to the Wi-Fi standard. Additionally, full-band capture unlocks advanced real-time spectral awareness across the frequency band. It creates a platform for interference monitoring, AI-driven performance optimization and network security across the range (vs one channel at a time).

What does this mean from a service perspective?

In high-density or high-interference applications in the home or enterprise markets, MCSR™ provides a powerful, patented hardware platform for service delivery. MCSR™ unlocks the potential of the wireless spectrum and enabling artificially intelligent Wi-Fi management software to have more granular control of the available Wi-Fi spectrum. This type of granular control of the spectrum envelope in Wi-Fi, allows service providers to engineer the Wi-Fi airways the same way an air traffic controller might engineer the airways for air travel. Different channels for different services, different data rates, or to combine non-bonded channels for ultra-low latency performance.

- For residential applications, being able to engineer the spectrum more granularly in both the 2.4 GHz and 5 GHz allows for the densification of services in the coverage area and unlocks applications such as:
    - Dual Channel Wi-Fi™: A revolutionary approach to alleviating jittery video and laggy gaming experiences, Dual Channel Wi-Fi enables one or more downlink-only data channels in concert with a standard bi-directional channel. Fully compatible with Edgewater's MCSR™, Dual Channel Wi-Fi unlocks the unused spectrum to reduce contention and latency while increasing airtime utilization dramatically. Developed for set-top boxes, TVs and soon, gaming platforms and iPads, Dual Channel

Wi-Fi can be implemented wherever traditional single-channel Wi-Fi struggles with contention – in residential and enterprise applications globally.

- Edgewater's proprietary **MESHD™** (Mesh High Density) application enables network operators to allocate channels to mesh applications while leaving other channels uncontended for other applications. Delivering a 7X performance gain over single-channel architectures, Edgewater's MCSR™ powered MESHD™ dramatically reduces operator deployment and support costs.

- **PowerZoning™** gives network operators, and service providers enhanced capabilities for improved RF management & planning while reducing or eliminating the impacts of Adjacent Channel Interference and Co-Channel Interference. PowerZoning™ control enables per channel power control allowing operators to create highly defined coverage zones with tightly controlled zone edges – maximizing frequency reuse for optimal high-density performance. PowerZoning is a feature only available with MCSR™-powered Access Points.

- **Intelligent Channel Association (ICS™)**: Powered by Edgewater's MCSR™ silicon solutions, ICS™ enables application-level channel allocation to optimize performance. Lower contention, interference-free channels can be allocated to latency-sensitive applications like gaming or HD TV video streaming. Low bandwidth or less latency-sensitive IoT applications can be assigned to separate channels. Overall network performance can be optimized across the spectrum, reducing customer care calls.

Similar to the transition from a single-lane road to a multi-lane highway, the applications are endless as fewer clients per channel allows for better wireless network performance.

Unlock the power of Wi-Fi Spectrum Slicing to beat the capacity crunch.

Edgewater Wireless' groundbreaking solutions – from chipsets to licensing -- are proven in major enterprises and service providers – Mediacom, Kroger Corporation, Nokia and Comcast – and are generating industry accolades from CableLabs UpRamp to the Wireless Broadband Alliance and the IEEE.

Targeting the multi-billion dollar Wi-Fi Access Point and Device markets, Edgewater's patented MCSR™ silicon solutions and, for large scale Silicon Companies, IP Licensing, offer a proven path to the next generation of Wi-Fi – today.

Momentum and validations

- **Mediacom:** Successfully completed first Cable Industry POC leading to a growing number of hospitality industry deployments. (https://tinyurl.com/wny6l3w)

- **Kroger:** First access point hardware design-win for Edgewater's MCSR™ silicon solutions

- **CableLabs:** one of four companies selected for the inaugural CableLabs backed accelerator program, UpRamp which validated Edgewater's revolutionary approach to Wi-Fi and lead to multiple MSO engagement. Multichannel News: https://tinyurl.com/t32s4lv

- **Dual Channel Wi-Fi™:** the emerging Dual Channel Wi-Fi™ standard, co-innovated with CableLabs, is the industry's first declaration that 'one channel is not enough' and is a first step toward multi-channel Wi-Fi

    - Light Reading: CableLabs Seeks to Supercharge Wi-Fi (https://tinyurl.com/w8r4ked)

- Video: Wi-Fi Spectrum Slicing's Killer App: Dual Channel Wi-Fi™ with Special Guest, Luther Smith, Senior Architect, CableLabs: https://www.edgewaterwireless.com/partners/webinars/

- **Wireless Broadband Alliance (WBA):** selected for the WBA Accelerator track which provide a global platform for introducing Wi-Fi Spectrum Slicing to members such as Intel, Broadcom, Qualcomm and British Telecom (BT). Video: https://www.youtube.com/watch?v=ot75yqB7ebw

- **Comcast & Nokia:** Successfully demonstrated 5G Interconnectivity demo with Comcast, Nokia and Global Reach, helping to establish Wi-Fi as a foundation to the emerging 5G standard and positioning Edgewater's technology with major industry players. Video: https://tinyurl.com/rexkn4u

- **Apple:** Completed a landmark deal for a non-core patent with Apple validating the IP portfolio.

Edgewater Wireless Systems Inc. (TSXV; YFI)

We make Wi-Fi. Better.

Edgewater Wireless (www.edgewaterwireless.com) is the industry leader in innovative Wi-Fi Spectrum Slicing technology for residential and commercial markets. A disruptive, next-generation approach to wireless, Wi-Fi Spectrum Slicing optimizes scarce spectrum to deliver demanding applications like video, gaming, and voice applications at the highest quality-of-service possible.

Backed by 24+ patents, we deliver high-performance MCSR™ silicon solutions, advanced, MCSR™ powered Access Points and Intellectual Property (IP) licensing to OEM[4] and ODM[5]; service providers; and silicon manufactures.

Do more with less! Fewer access points delivering high-quality service at a lower overall deployment cost make our patented MCSR™ technology the right choice for your next Wi-Fi network.

Explore the evolution of Wi-Fi at www.EdgewaterWireless.com or www.aera.io

[4] OEM refers to Original Equipment Manufacturers or companies who manufacture products for other companies (Source: https://en.wikipedia.org/wiki/Original_equipment_manufacturer)
[5] ODM refers to Original Design Manufacturers or companies who manufacture products which are in term rebranded by another company (Source: https://en.wikipedia.org/wiki/Original_design_manufacturer)