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Low Latency Testing Services Webinar

June 14, 2023

🌐 kyrio.com

The Problem
Reliable Low Latency Testing is Complex and Unreliable

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Low latency is better signal of QoE than speed.

Traditional speed testing does not factor in application performance.

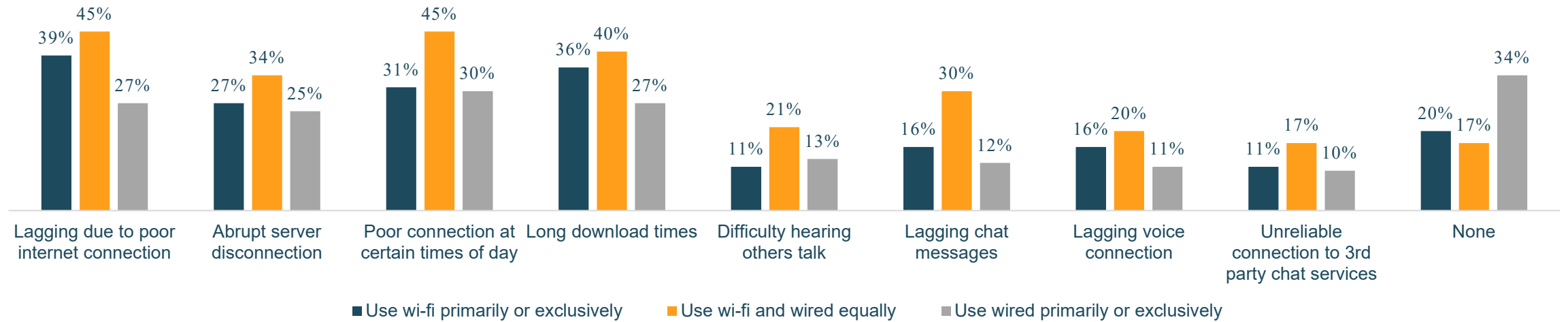DUT engineering design is not optimized for the customer experience.

> The key network attribute for end-user QoE is not solely bandwidth capacity but also latency. Thus, end user quality depends not just on throughput (what many network test web sites still report as "speed") but also on latency; both are important.
>
> Broadband Internet Technical Advisory Group (BITAG), Latency Explained (2022)

Latency: Observable Pain Points

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Lagging due to poor internet connection: 39%, 45%, 27%
Abrupt server disconnection: 27%, 34%, 25%
Poor connection at certain times of day: 31%, 45%, 30%
Long download times: 36%, 40%, 27%
Difficulty hearing others talk: 11%, 21%, 13%
Lagging chat messages: 16%, 30%, 12%
Lagging voice connection: 16%, 20%, 11%
Unreliable connection to 3rd party chat services: 11%, 17%, 10%
None: 20%, 17%, 34%

■ Use wi-fi primarily or exclusively ■ Use wi-fi and wired equally ■ Use wired primarily or exclusively

Primary Research conducted by CableLabs 2017-2020, including Focus Groups with Power Users, Gamers
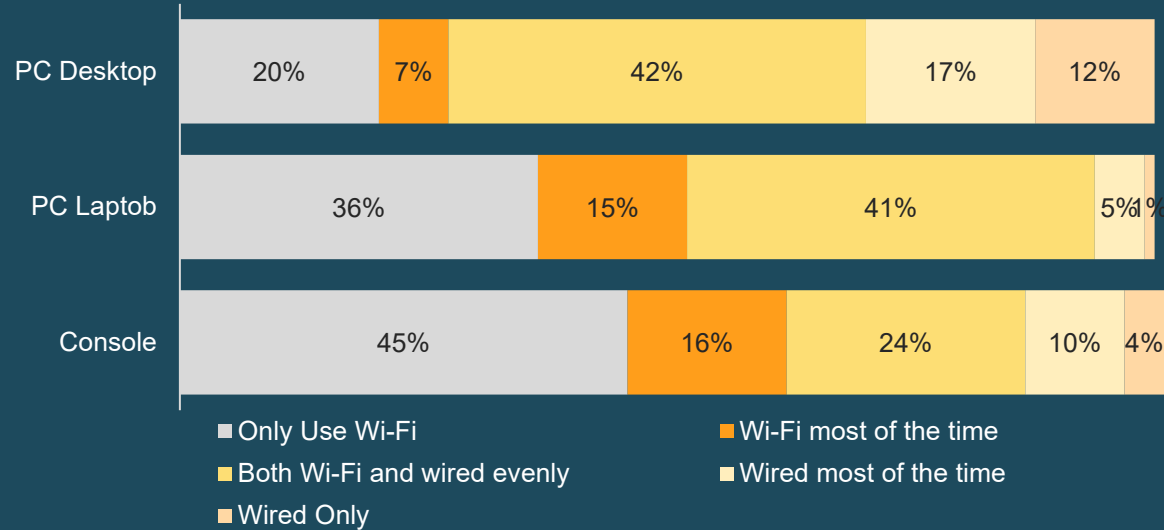
Consumer surveys of 1000+ US Cable Internet Gamer Subs; play 3+ times/week for 1+ hour/session

Survey limited to relevant Xbox, PS and PC platforms

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Is Wi-Fi Low Latency a Better Signal for QoE than Speed?

51% primarily use Wi-Fi for gaming: only 16% are primarily wired

Platform	Only Use Wi-Fi	Wi-Fi most of the time	Both Wi-Fi and wired evenly	Wired most of the time	Wired Only
PC Desktop	20%	7%	42%	17%	12%
PC Laptop	36%	15%	41%	5%	1%
Console	45%	16%	24%	10%	4%

- Only Use Wi-Fi
- Wi-Fi most of the time
- Both Wi-Fi and wired evenly
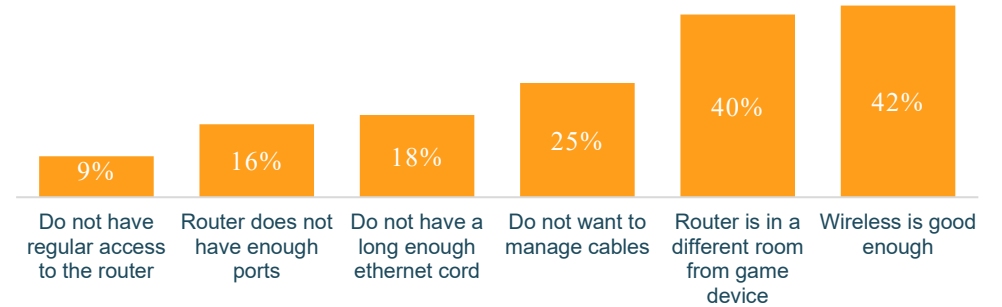- Wired most of the time
- Wired Only

- ✓ QoE for applications that are more interactive or real-time, like web browsing, online gaming, and video conferencing is impacted by latency.
- ✓ Increasing bandwidth without addressing latency may not improve QoE.
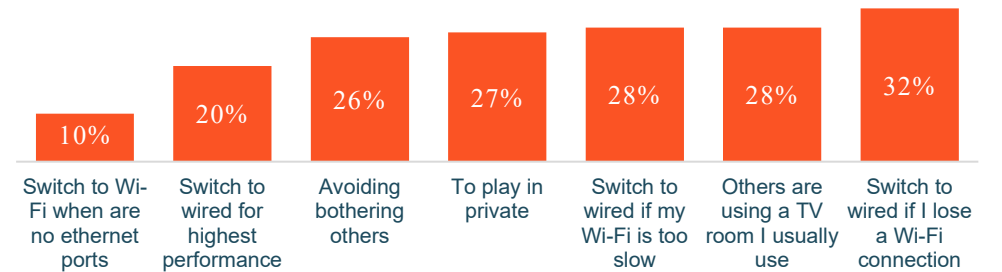
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58% believe Wi-Fi is not good enough for gaming

Why Gamers do not exclusively use wired connections

Do not have regular access to the router	Router does not have enough ports	Do not have a long enough ethernet cord	Do not want to manage cables	Router is in a different room from game device	Wireless is good enough
9%	16%	18%	25%	40%	42%

One in three switch to wired connection due to poor Wi-Fi performance

Why Players switch between Wi-Fi and wired connections

Switch to Wi-Fi when are no ethernet ports	Switch to wired for highest performance	Avoiding bothering others	To play in private	Switch to wired if my Wi-Fi is too slow	Others are using a TV room I usually use	Switch to wired if I lose a Wi-Fi connection
10%	20%	26%	27%	28%	28%	32%

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- Consumer surveys of 1000+ US Cable Internet Gamer Subs; play 3+ times/week for 1+ hour/session.
- Survey limited to relevant Xbox, PS and PC platforms.

5

# Sebnem Ozer, Ph.D.
Charter Communications

- Over 20 years of industry expertise as a systems and product lead.

- Currently, holding the position of Principal Architect III at Charter Communications, leading the development of low latency access networks.

- Prior to joining Charter Communications, worked as a system architect and manager at Comcast, Arris, Google, Motorola, and Meshnetworks.

- Technical knowledge spans wired and wireless networks, including HFC and PON Networks, Wi-Fi/Mesh and Mobile Networks, data driven QoE analytics, Software Defined Networks, and Network Functions Virtualization.

- Ph.D. in electrical and computer engineering from the New Jersey Institute of Technology.

- Authored numerous patents, publications, and has participated as a speaker in various engagements.

- **We need consistent E2E latency for a superior user experience**

- **More bandwidth does not guarantee consistent low latency and jitter**

- **Active queue management with congestion notification is key for the success of low latency applications.**
  - **Not defined in the Wi-Fi standards yet**

- **Latency management should be conducted within the time window of Wi-Fi network and traffic fluctuations.**
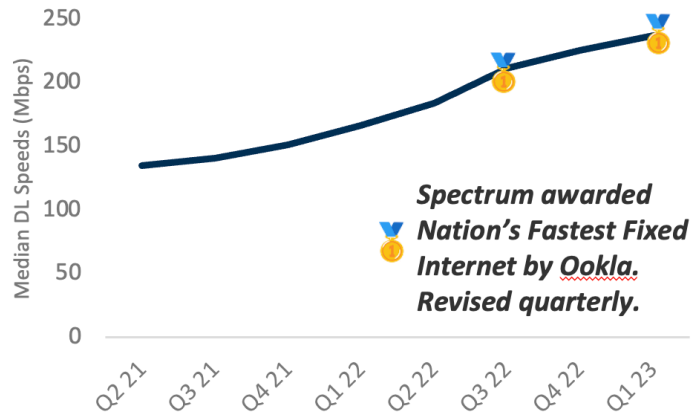
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Consistent Superior User Experience

Charter Offers Ubiquitous Gigabit Speeds [1]
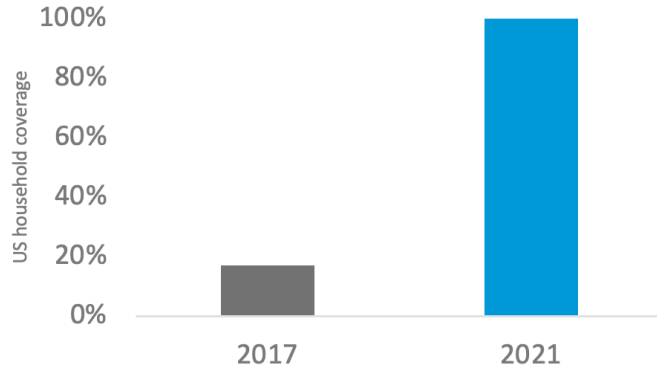
Charter Speeds Up Over 75% in 2 Years [2]


Spectrum awarded Nation's Fastest Fixed Internet by Ookla. Revised quarterly.

- **Quality of Experience** is a function of QoS and other system-related factors, and human and context-related factors.
- **Quality of Service** is a function of throughput, latency, jitter, packet loss, reliability, security… that can be measured and monitored in *real-time.*

Charter only - SamKnows Downstream Latency Under Load CDF [3]

4/27/23-5/11/23
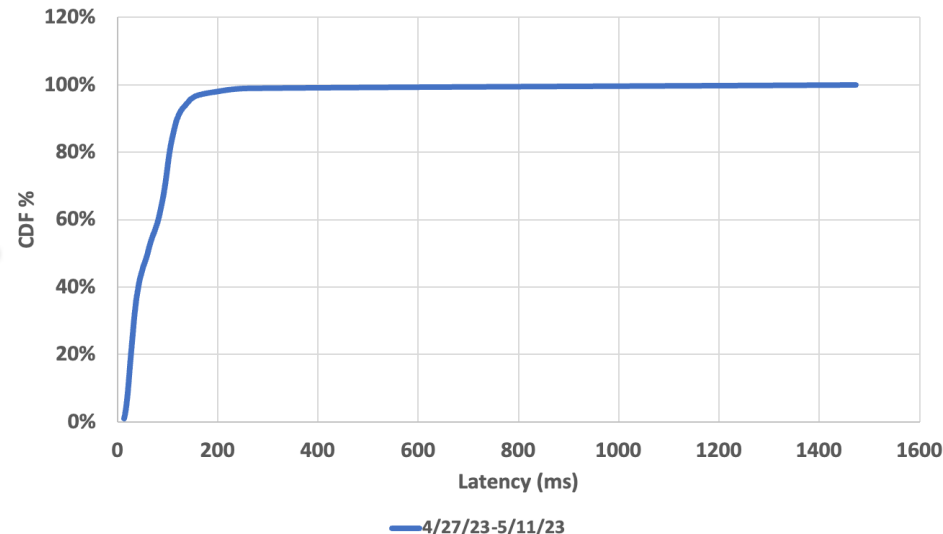
- About latency…
  - Idle Latency & Latency Under Load
  - Consistent latency : low jitter
  - Percentiles (not mean/median)

- About latency measurement…
  - Active vs Passive
  - Queue Building vs Non-Queue Building
  - End-to-end vs Hop-by-hop
  - Measuring latency factors for troubleshooting & prediction
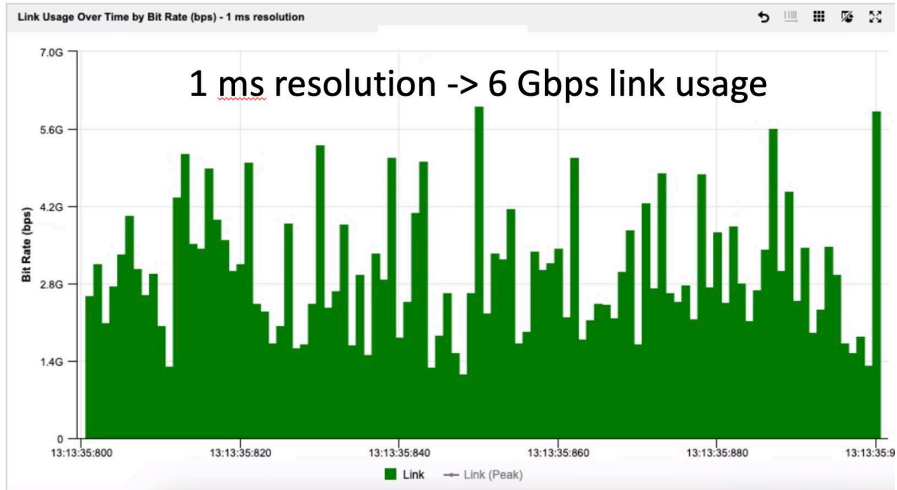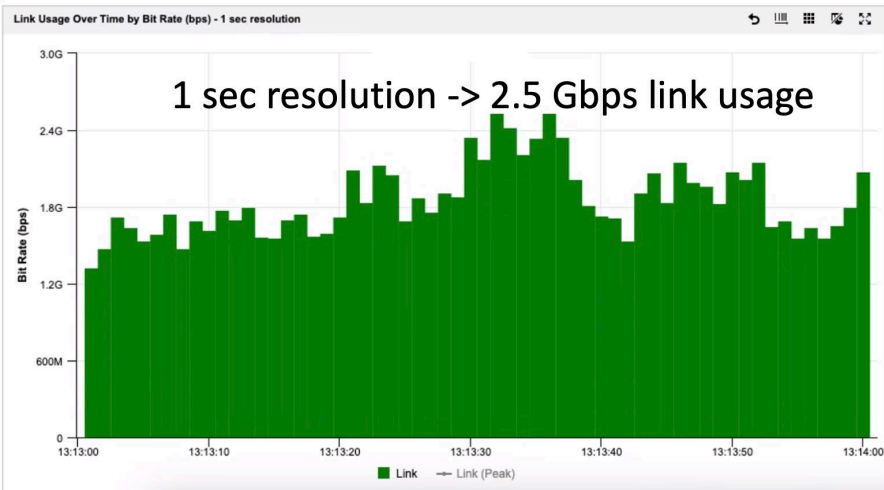
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Low Latency and Jitter for Current and Emerging Services

- **Why increasing speed alone is not enough?**
- Non-speed related factors affecting latency and its variation (jitter)
- Induced demand in terms of customer usage and emerging applications
  - Single to low double digit ms latency and jitter
  - "real time" in services vs network timeframe
- End-to-end system efficiency
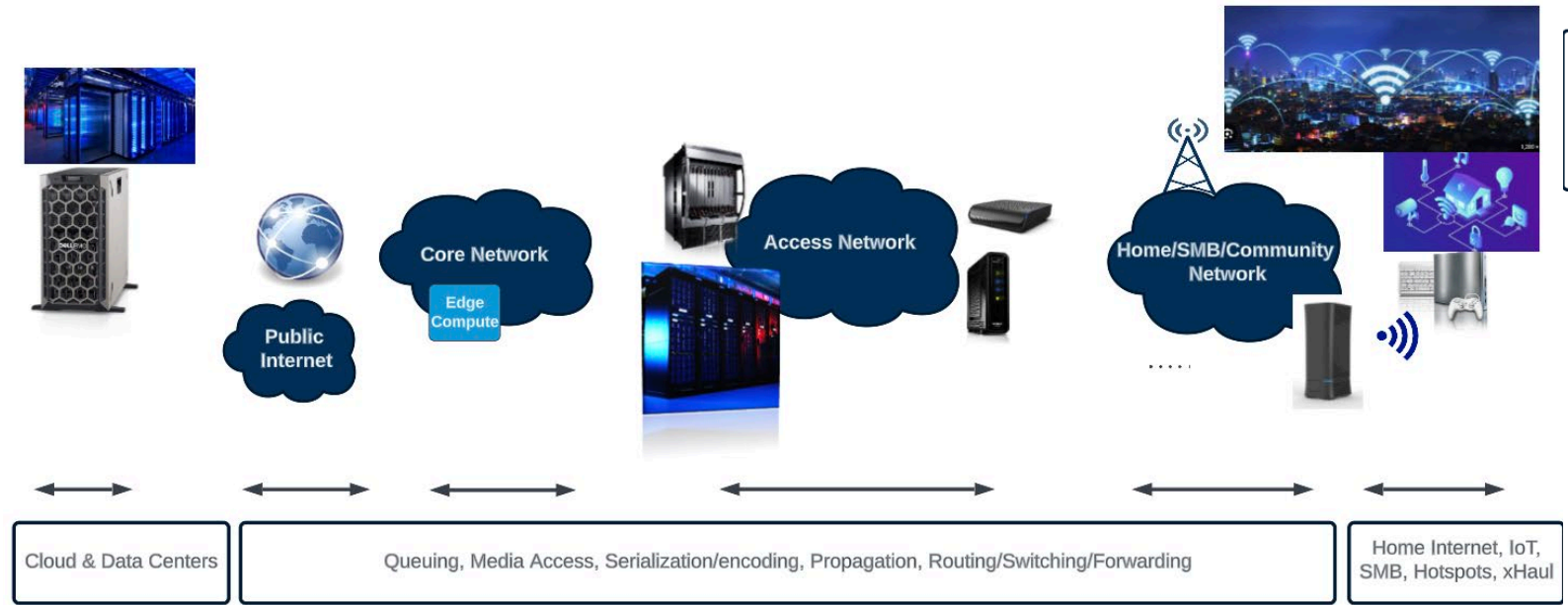
Gaming, videoconferencing, live & interactive streaming, IoT, AR/VR, tele-medicine, tele-education, tele-retail,...

Public Internet

Core Network

Edge Compute

Access Network

Home/SMB/Community Network

Cloud & Data Centers

Queuing, Media Access, Serialization/encoding, Propagation, Routing/Switching/Forwarding

Home Internet, IoT, SMB, Hotspots, xHaul

APP TOTAL VOLUME 2022

	Application	Total Volume
1	Netflix	13.74%
2	YouTube	10.51%
3	Generic QUIC	5.41%
4	HTTP Media Stream	4.33%
5	Disney+	4.20%
6	Tik Tok	3.55%
7	Facebook	2.83%
8	Xbox Live	2.71%
9	Playstation Downloads	2.70%
10	Amazon Prime	2.67%

Link Usage Over Time by Bit Rate (bps) - 1 sec resolution

1 sec resolution -> 2.5 Gbps link usage

Link Usage Over Time by Bit Rate (bps) - 1 ms resolution

1 ms resolution -> 6 Gbps link usage

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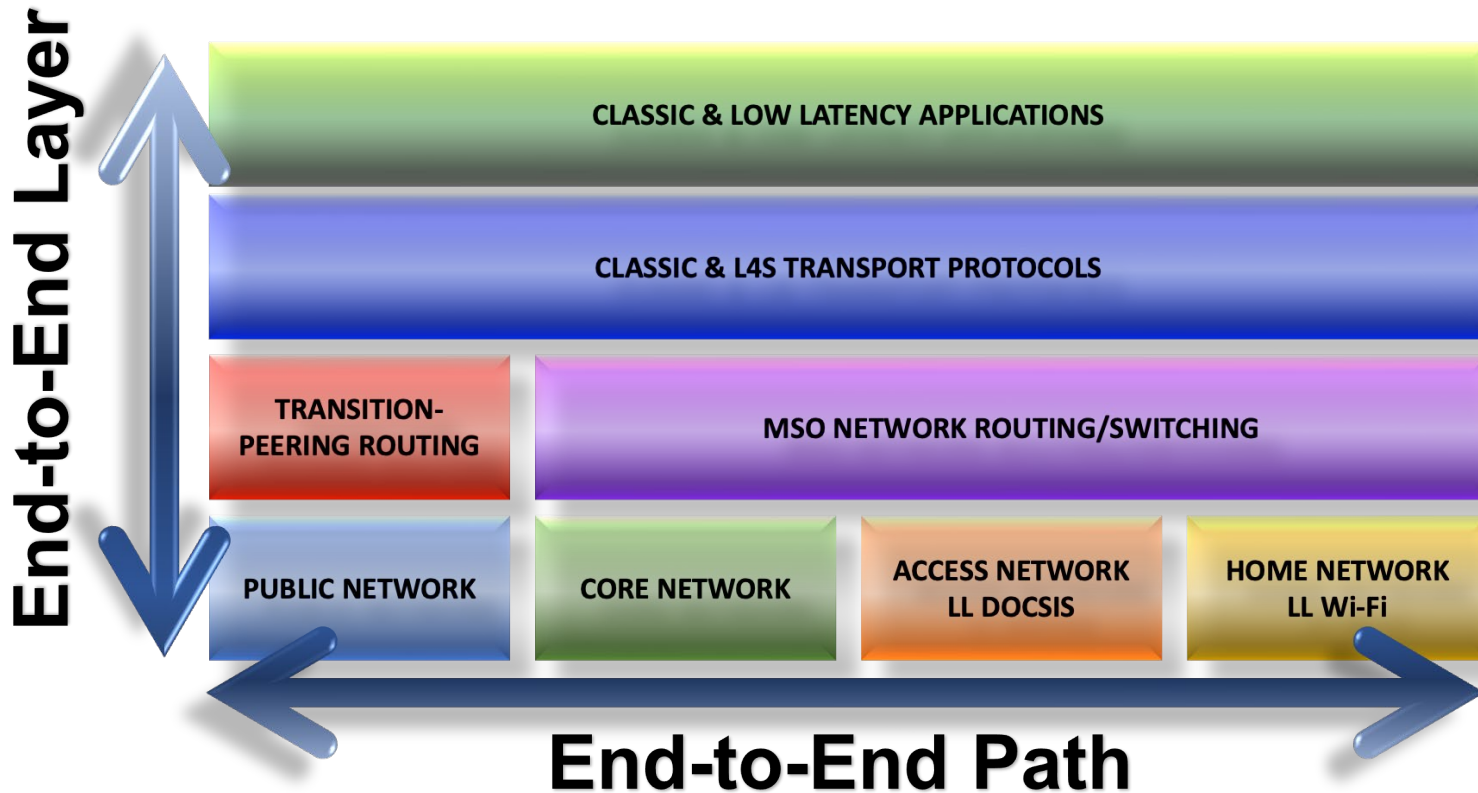
Multidimensional QoS Framework
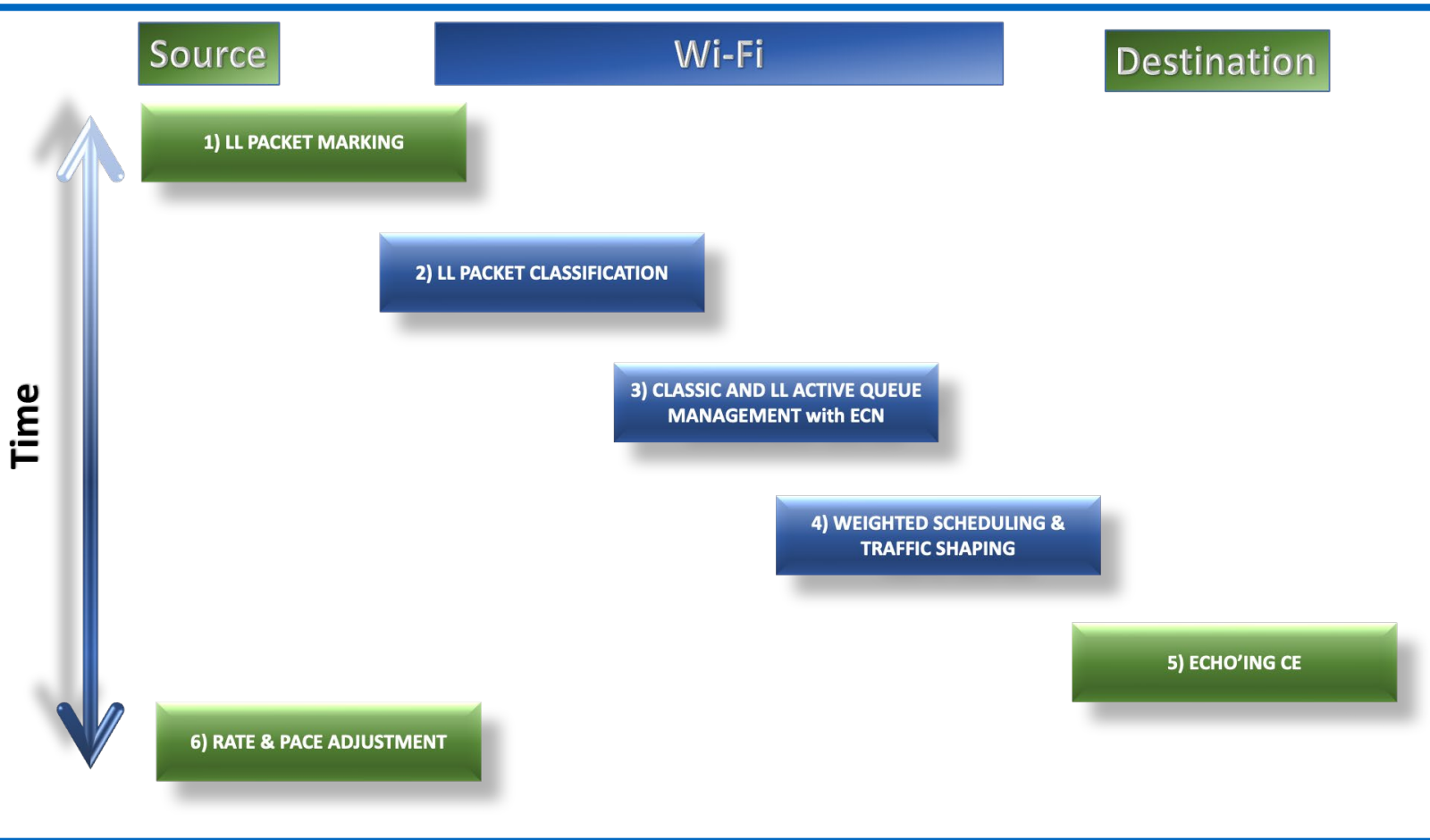
- **Service Quality**
  - Multidimensional Dependency along the network path and OSI layers and between them
  - Main network latency and jitter factors:
    - Queueing & media access
  - Different network segments and components may be the "bottleneck" with a particular "bottleneck characteristic"
    - e.g., high latency vs high jitter bottleneck

- **Wi-Fi Latency and Jitter Performance**
  - QoS Measurements
    - impact on "real-time" services
    - Correlation and causation analysis
  - QoS management
    - Integrated management for queuing, media access and airtime usage
    - Congestion notification to transport layers

Wi-Fi Extensions for Low Latency and Jitter

Time

Source | **Wi-Fi** | **Destination**

1) LL PACKET MARKING

2) LL PACKET CLASSIFICATION

3) CLASSIC AND LL ACTIVE QUEUE MANAGEMENT with ECN

4) WEIGHTED SCHEDULING & TRAFFIC SHAPING

5) ECHO'ING CE

6) RATE & PACE ADJUSTMENT

- **Wi-Fi Extensions**
  - Traffic classification
    - Low-rate non-queue-building
    - High-rate NQB (e.g. IETF L4S)
  - Active queue management for classic and low latency traffic
  - Granular and accurate ECN
  - Weighted scheduling
  - Interworking with WMM and new deterministic QoS features

Extending AQM Support:
https://mentor.ieee.org/802.11/dcn/23/11-23-0650-01-0uhr-qos-re-visited.pptx
https://mentor.ieee.org/802.11/dcn/23/11-23-0679-00-0uhr-low-latency-qos-based-on-l4s.pptx

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RFC 1121   Act One - The Poems   September 1989

```
                     ODE TO A QUEUE
                          by
                   Leonard Kleinrock

In the 20 years of funding
Many fields has DARPA led.
But the finest thing that they did bring
Was the analytic thread.

By that I mean they nurtured
Quantitative research tools.
And they always felt for all their gelt
They got principles and rules.

Indeed a wealth of knowledge
Was uncovered and was new.
And the common thread with which we led
Was the analytic queue!

Now a queue may have one server.
If there's more, they form a team.
Its dearest wish is just to fish
In a quiet Poisson stream.

If you want to model networks
Or a complex data flow
A queue's the key to help you see
All the things you need to know.

So the next time you feel lonely
And wonder what to do,
You'll soon feel fine if you join the line
Of an analytic queue!
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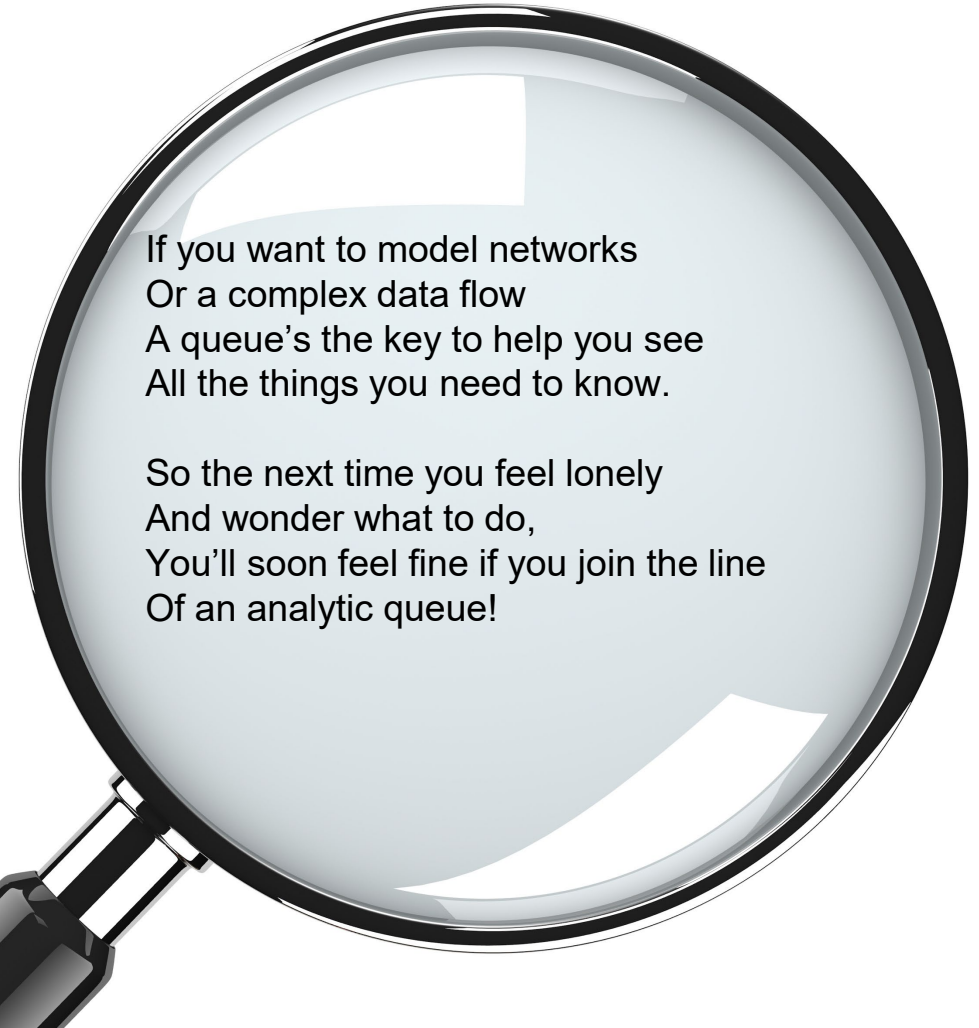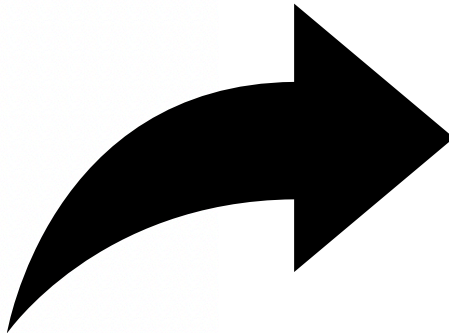
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How to drive Wireless & Wired Connection to the next generation:

- Understanding the Importance of Low Latency

- Mastering Latency Testing Techniques

- Why the latency is important to the costumer

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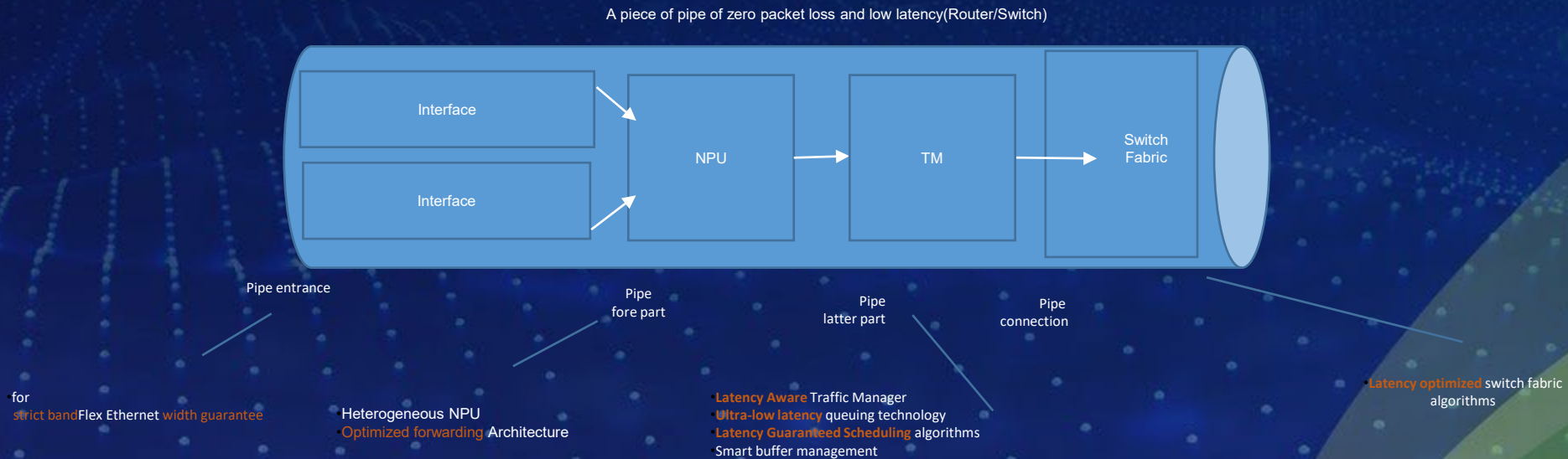| essential difference	Key Feature Differences	5G	WiFi 6
License VS Unlicensed	spectrum	Dedicated spectrum	Shared spectrum
	Compatible with previous protocols	2G/3G/4G/5G uses different frequency bands, and air interface protocols do not need to be compatible with different RATs.	802.11a/n/ac/ax works on the 5 GHz frequency band. Air interface protocols need to be backward compatible, causing overheads.
	Access mechanism	Negotiation + Scheduling	CSMA/CA + UORA can be sent by contending for a channel.
	Processing Delay	Minimum PUSCH feedback duration: 410 us (23 symbols) Minimum uplink protocol duration: 160 us (9 symbols)	16 µs must be processed and the feedback must be sent. Otherwise, channel preemption is affected.
Network performance	RF unit power	RRU 8T8R power 80W*2	AP power 2W
	Handover	Cell merged and handover can be reduced	Each AP one cell , handover between AP
	Capacity	New function DMM, super uplink base on 5G network	AP capacity is certain
Synchronous VS Asynchronous	Frame structure	Strict synchronization of frames and subframes	flexible frame structure
	MIMO	A maximum of 12 ports and 16 streams are supported. Support for D-MIMO	Up to eight streams D-MIMO is difficult to support.
	Dispatching	centralized scheduling	Uplink-triggered scheduling, with management frames (such as BSR), requiring CSMA
	HARQ	Supporting HARQ	Not supported
Architecture	System Architecture	LampSite distributed architecture and IRC algorithm	In the AP architecture, IRC is not supported due to limited pilot and processing delay requirements.
Dedicated Control Channel vs Unified Channel	Channel mapping	Control and data use different channel mappings	Signaling and IEs are connected and distinguished by the type field.
	pilot frequency	orthogonal pilot design	nonorthogonal
URLLC-specific Enhancements	URLLC Special Design	Slot aggregation, 1e-5 CQI/MCS table, PDCCH 16CCE aggregation, etc.	None

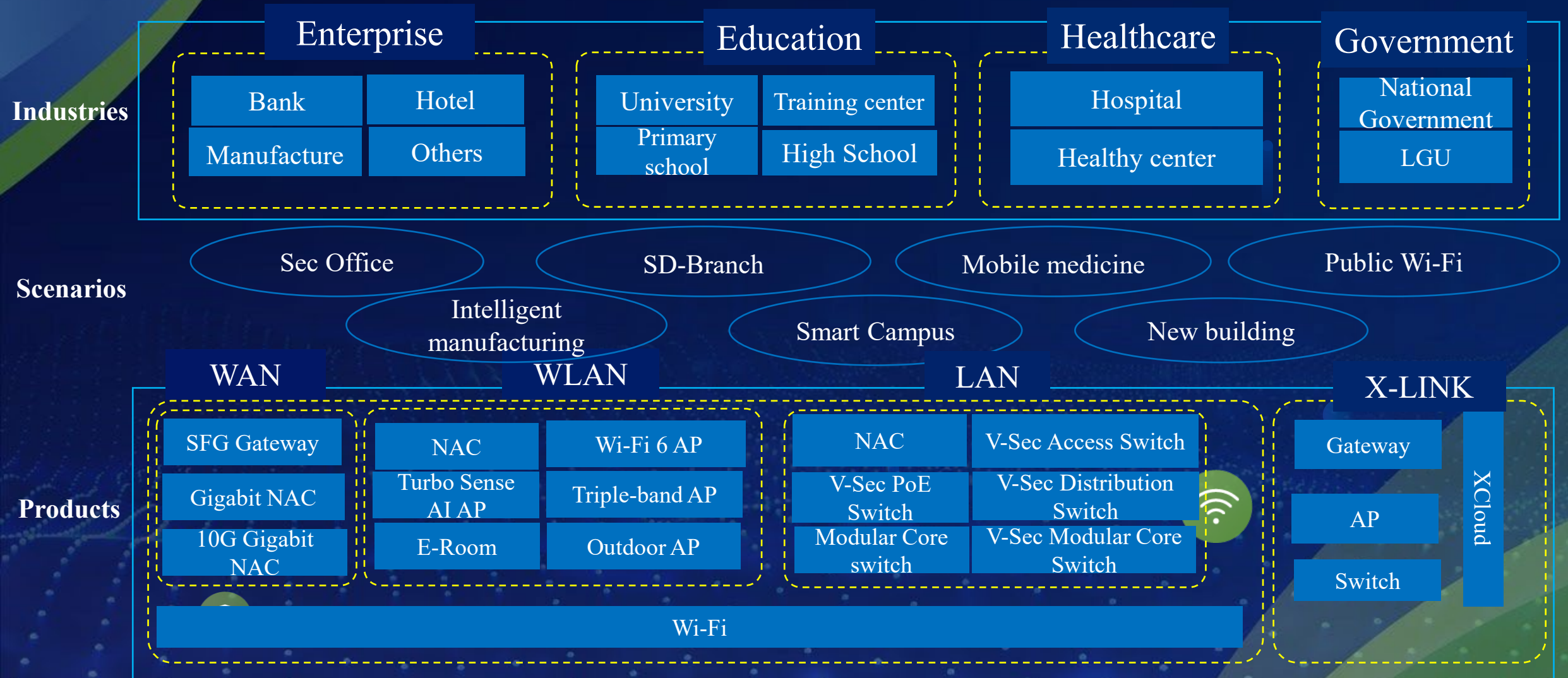Kyrio Lab

What Is Network Latency?

Latency refers to the speed of your network traffic, which is measured in milliseconds, with higher numbers indicating slower connections. What constitutes an acceptable latency range will vary not only network by network, but also application by application.
Devices & applications needing more network bandwidth, such as video or VoIP calls, will require lower latency ranges to function properly and efficiently. On the other hand, the less instantaneous nature of email delivery allows for a higher latency range when determining bandwidth priorities.

Part of the responsibilities of a network administrator includes deciding how to allocate bandwidth and resources to ensure users can do their jobs in a timely manner to help keep company operations running smoothly.

A piece of pipe of zero packet loss and low latency(Router/Switch)

Interface

Interface

NPU

TM

Switch Fabric

Pipe entrance

Pipe fore part

Pipe latter part

Pipe connection

for strict bandFlex Ethernet width guarantee

Heterogeneous NPU
Optimized forwarding Architecture

Latency Aware Traffic Manager
Ultra-low latency queuing technology
Latency Guaranteed Scheduling algorithms
Smart buffer management

Latency optimized switch fabric algorithms

Wi-Fi Key Business Overview

Industries

Enterprise		Education		Healthcare	Government
Bank	Hotel	University	Training center	Hospital	National Government
Manufacture	Others	Primary school	High School	Healthy center	LGU

Scenarios

Sec Office   SD-Branch   Mobile medicine   Public Wi-Fi

Intelligent manufacturing   Smart Campus   New building

Products

WAN
- SFG Gateway
- Gigabit NAC
- 10G Gigabit NAC

WLAN
NAC	Wi-Fi 6 AP
Turbo Sense AI AP	Triple-band AP
E-Room	Outdoor AP

LAN
NAC	V-Sec Access Switch
V-Sec PoE Switch	V-Sec Distribution Switch
Modular Core switch	V-Sec Modular Core Switch

X-LINK
- Gateway
- AP
- Switch

XCloud

Wi-Fi

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The Main Advantages Low Latency Wi-Fi

Improved Responsiveness:

Low latency ensures that there is minimal delay between sending a command or request and receiving a response.

This leads to a more responsive and interactive user experience, especially in applications that require real-time communication or quick interactions, such as online gaming or video conferencing.

Enhanced Gaming Experience:

Gamers rely on low latency Wi-Fi to reduce input lag and ensure faster response times in multiplayer games. It enables more precise and accurate control, providing a competitive edge and a smoother gameplay experience.

Seamless Video Streaming

Low latency Wi-Fi allows for seamless streaming of high-definition videos, reducing buffering times and eliminating interruptions. It ensures that video content starts quickly and plays smoothly without noticeable delays, enhancing the overall viewing experience.

4 Ways of Value-Added Low Latency & Jitter Wi-Fi

To achieve value-added low latency Wi-Fi, it's important to consider factors such as network infrastructure, quality of service (QoS) settings, interference management, & proper network configuration. These factors can optimize the Wi-Fi environment and ensure that low latency is consistently maintained to deliver the desired benefits.

Enhanced User Experience:

Low latency Wi-Fi improves the overall user experience by reducing delays and improving responsiveness in applications that require real-time interaction. This includes activities such as online gaming, video streaming, video conferencing, and voice over IP (VoIP) calls. By minimizing latency, users can enjoy smoother, more immersive experiences without noticeable delays or lag.

IoT Device Connectivity

Low latency Wi-Fi is crucial for connecting and controlling Internet of Things (IoT) devices. Many IoT applications, such as home automation, security systems, and smart devices, rely on low-latency connections to enable quick responses and real-time monitoring. By reducing latency, low latency Wi-Fi enhances the reliability and

effectiveness of IoT ecosystems.

Business Efficiency:

In business environments, low latency Wi-Fi can improve productivity and efficiency. It enables faster data transfer, seamless collaboration, and real-time access to cloud-based applications and services. Employees can collaborate on projects, access critical information, and make decisions more efficiently, leading to improved workflow and productivity.

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Critical Applications:

Low latency Wi-Fi is essential for certain industries and applications that demand immediate response times. For example, in sectors like finance, healthcare, and manufacturing, low latency is critical for real-time data analysis, remote monitoring, and control systems. By implementing low latency Wi-Fi, these industries can benefit from faster data processing, improved accuracy, and timely decision-making.

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Challenge of New Business

4K/8K Video

- ITU-R BT.2020 4K/UHD video standard support 120p、60p、50p、30p、25p etc.

- Bandwidth requirement:
  - 35Mbps for 4K, 75Mbps for Ultra 4K,
  - 140Mbps for 8K, 330Mbps for Ultra 8K

- 4K video require RTT(Round Trip Time) **below 35ms**, even less for 8K video.

VR/AR

- People feel dizzy since users' motion perception is not match with images(Motion sickness), need to get latency down to **20 ms**, or possibly much less.

- AR are more latency sensitive than immersive VR, because real world objects have no latency and delays of virtual objects can be seen directly.
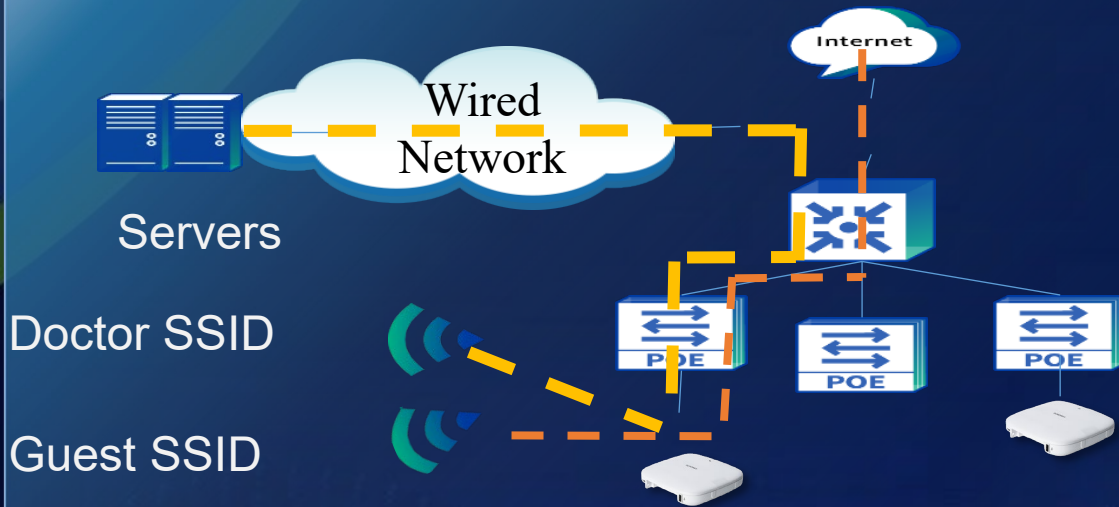
Smart Grid
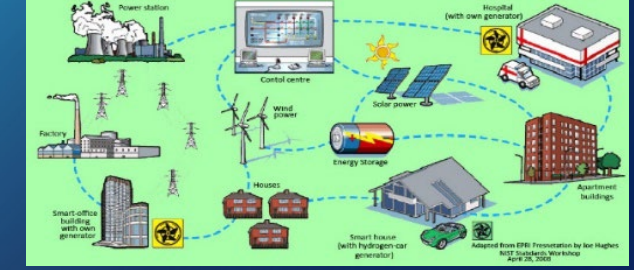
- Smart grid is a generic label for the application of computer intelligence and networking abilities to a dumb electricity distribution system.

- Latency requirements for smart grid vary from less than **10 ms** for teleprotection, to about **20 ms** for some synchrophasors applications, to **100-200 ms** for smart grid control, to up to **several seconds** for smart metering.

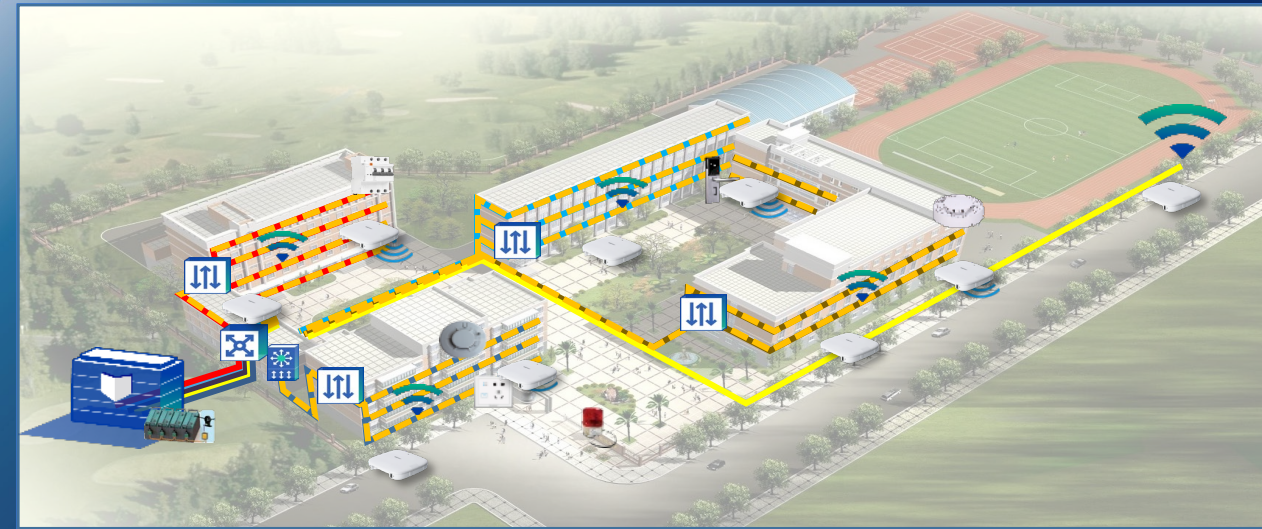*Challenge*:   Need a solution to provide strictly assured service performance in 5G & WiFi network

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Wi-Fi Scenarios:

Healthcare

Education

Healthcare diagram labels:
Internet
Wired Network
Servers
Doctor SSID
Guest SSID
POE
POE
POE

- 💡 **Network Separation**
- 💡 **Co-channel Solution, Faster Roaming**
- 💡 **Guest Access Detection**
- 💡 **Ads Push & Questionnaire**

- 💡 **Full Wi-Fi Coverage Campus**
- 💡 **APP and URL Filtering**
- 💡 **School ID login**
- 💡 **Ads Push and Questionnaire**
- 💡 **E-Class**

THANK YOU

Connectivity Senior Engineer

Liberty Latin America

David Dickson

David.Dickson@lla.com

Diagnose Latency Issues at Each Stage
Improve QoE and Move Beyond the Speed

Capture Latency Performance & Throughput Values

1

Understand Loading & Application Performance

2

Optimize Product Design for Real-World Traffic Scenarios

3

Design Wi-Fi Network for Specific Mix of Users

4

Differentiate Products & Services

5

How Low Can it Go?
Wi-Fi 6e and 7

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Wi-Fi 6e

More channels with 6GHz band

- ⊘ Less congestion and interference
- ⊘ Faster data transfer
- ⊘ Lower overall latency

Target Wake Time (TWT)

- ⊘ Reduces power consumption via efficient scheduling for connected devices

Wi-Fi 7

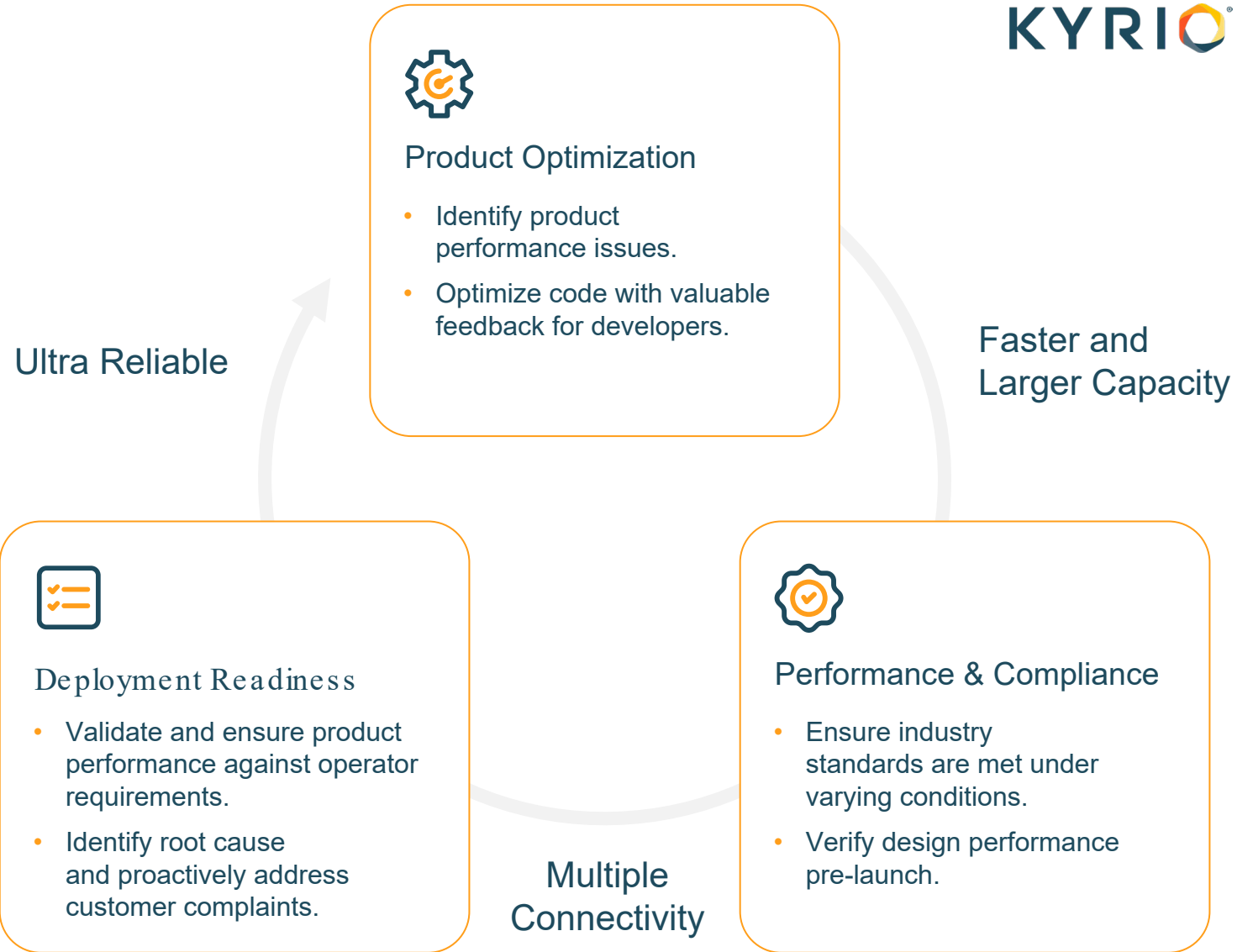**Low Density Parity Check (LDPC)**

- ⊘ Improves modulation and coding techniques

Higher number of spatial streams (up to 16)

- ⊘ Reduce packet loss
- ⊘ Improve reliability
- ⊘ Faster data transfer

Optimizing for Low Latency:
Product Testing at Each Lifecycle Stage

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Product Optimization

- Identify product performance issues.
- Optimize code with valuable feedback for developers.

Ultra Reliable

Faster and Larger Capacity

Deployment Readiness

- Validate and ensure product performance against operator requirements.
- Identify root cause and proactively address customer complaints.

Multiple Connectivity

Performance & Compliance

- Ensure industry standards are met under varying conditions.
- Verify design performance pre-launch.

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Kyrio Low Latency Testing
Built for Real World Integration

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Standardized, Neutral Testing Environment

Controlled and consistent to specific variables like radio frequency and traffic profiles

1

The Right Prioritization of Traffic

Differentiated Services Code Points (DSCP) apply multiple WWM Access Labels to prioritize traffic

2

Variety of Traffic Models

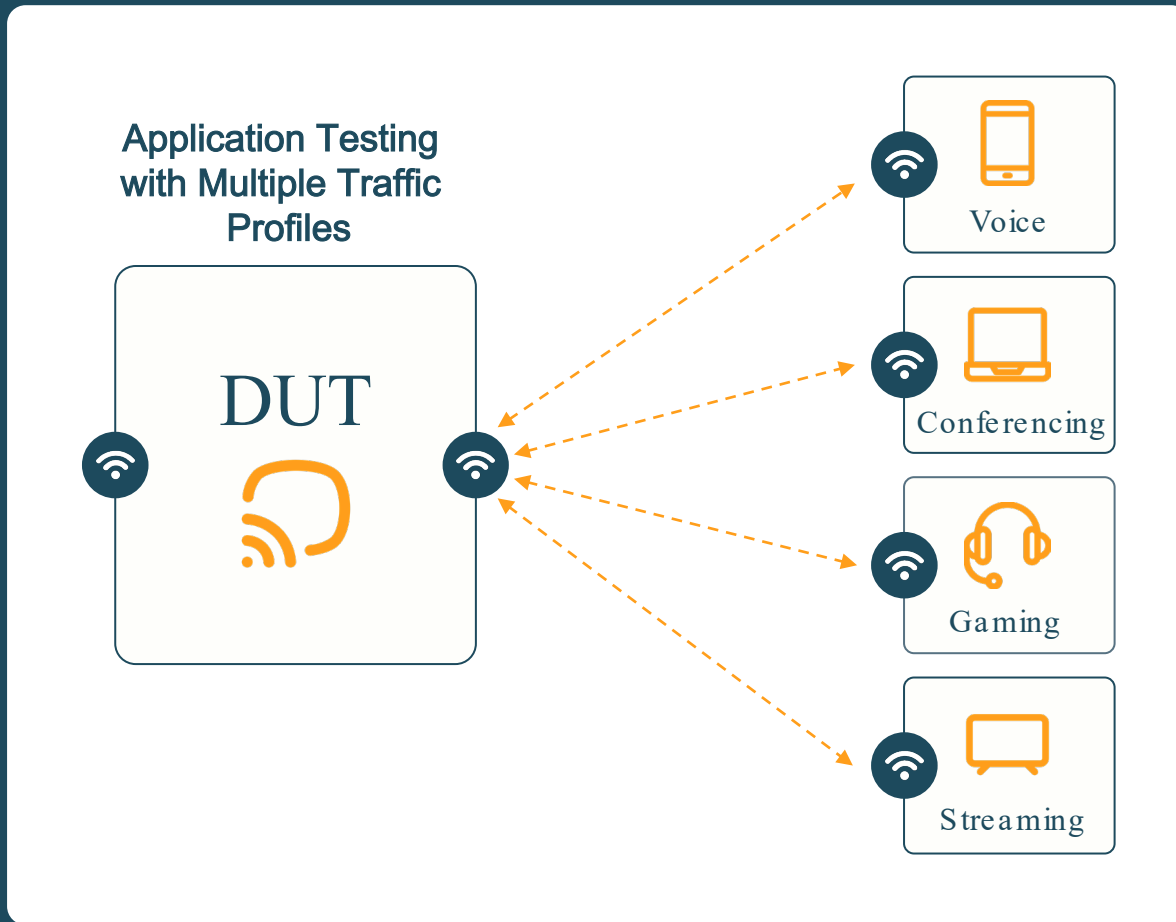Capture and predict variations on performance using real-world traffic

3

Actionable Insights

Capture latency and its associated KPIs, throughput, airtime fairness, packet loss, and performance under loaded conditions.

4

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Kyrio Latency Performance

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Application Testing with Multiple Traffic Profiles
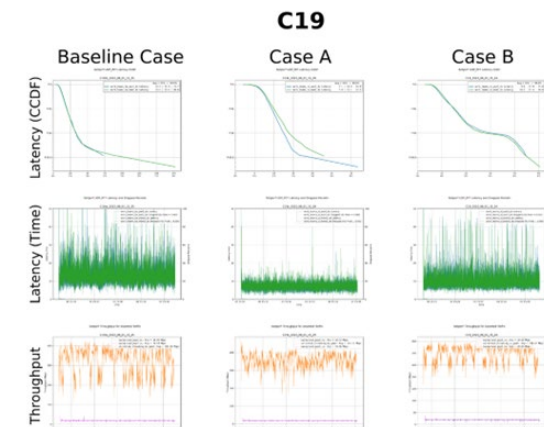
DUT

Voice

Conferencing

Gaming

Streaming

Launch:

Various configurations of traffic profiles are used with client applications, including custom traffic combinations.

Actionable KPIs

- ☑ Throughput
- ☑ Latency
- ☑ Airtime Fairness
- ☑ Packet Loss
- ☑ Behavior Under Loaded Conditions

C19 — Baseline Case, Case A, Case B (Latency CCDF, Latency Time, Throughput)

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Low Latency Testing Benefits

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Multiple, Real -World Traffic Models

- Built to generate traffic using Differentiated Services Code Points (DSCP), our models provide more accurate latency testing than traditional speed test models.
- Variety of internally developed models capture variations on performance.

Controlled Testing Environment

- Controlled RF environment and traffic profiles.
- Customizable to support multiple consumer use case patterns.

Kyrio Advantage

- Premier wireless, neutral testing lab in the world.
- State-of-the-art automated, full-featured RF test environment.
- Detailed reports provide actionable intelligence.
- Deep experience as independent arbitrator and host of industry interoperability events.
- Test parameter data based on insights from world's largest network operators.

Trust Experience.
Trust Kyrio.

KYRIO®

Thank You

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