

Qualcomm

@QCOMResearch

San Diego, CA

November 2023

# 5G Advanced: The path toward a more sustainable future

# We are enabling a more sustainable world

Where everyone and everything can be intelligently connected



# Best-in-class technology scalable to enable virtually every device

On-device intelligence

High performance, low power

Wireless everything



Edge AI



Processing



Graphics



Camera



Multimedia



Connectivity and RF

## Intelligent computing everywhere



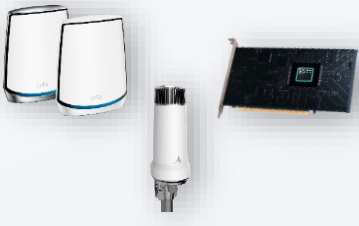
Handsets



Automotive



Consumer IoT



IoT edge networking



Industrial IoT

OUR COMMITMENT TO

# ESG

Environmental, Social,  
Governance

## Purposeful innovation



### Empowering digital transformation

- Equitable access
- Breakthrough inventions
- Future-focused R&D



### Acting responsibly

- Workforce
- Business integrity
- Ethical governance



### Operating sustainably

- Sustainability goals
- Resource management
- Operational resilience

# Our continued focus on sustainability



**100%**

renewable purchased electricity for our San Diego headquarters



**10%**

reduction in power consumption, every year in our flagship Snapdragon<sup>®</sup> products by 2025<sup>1</sup>



**50%**

reduction in Scope 1 and 2 greenhouse gas emissions by 2030



**25%**

reduction in Scope 3 emissions by 2030

**Net-zero**

The SBTi<sup>2</sup> has verified Qualcomm's net-zero science-based target by 2040

# Wireless is a catalyst for realizing our vision

A future that is economically, socially, and environmentally sustainable

# What are the three pillars of sustainability?



## Economic

Fueling growth by increasing productivity and efficiency, derived through new values, business models, and markets



## Social

Elevating quality of life and promoting digital equity and inclusion, improving affordability and availability

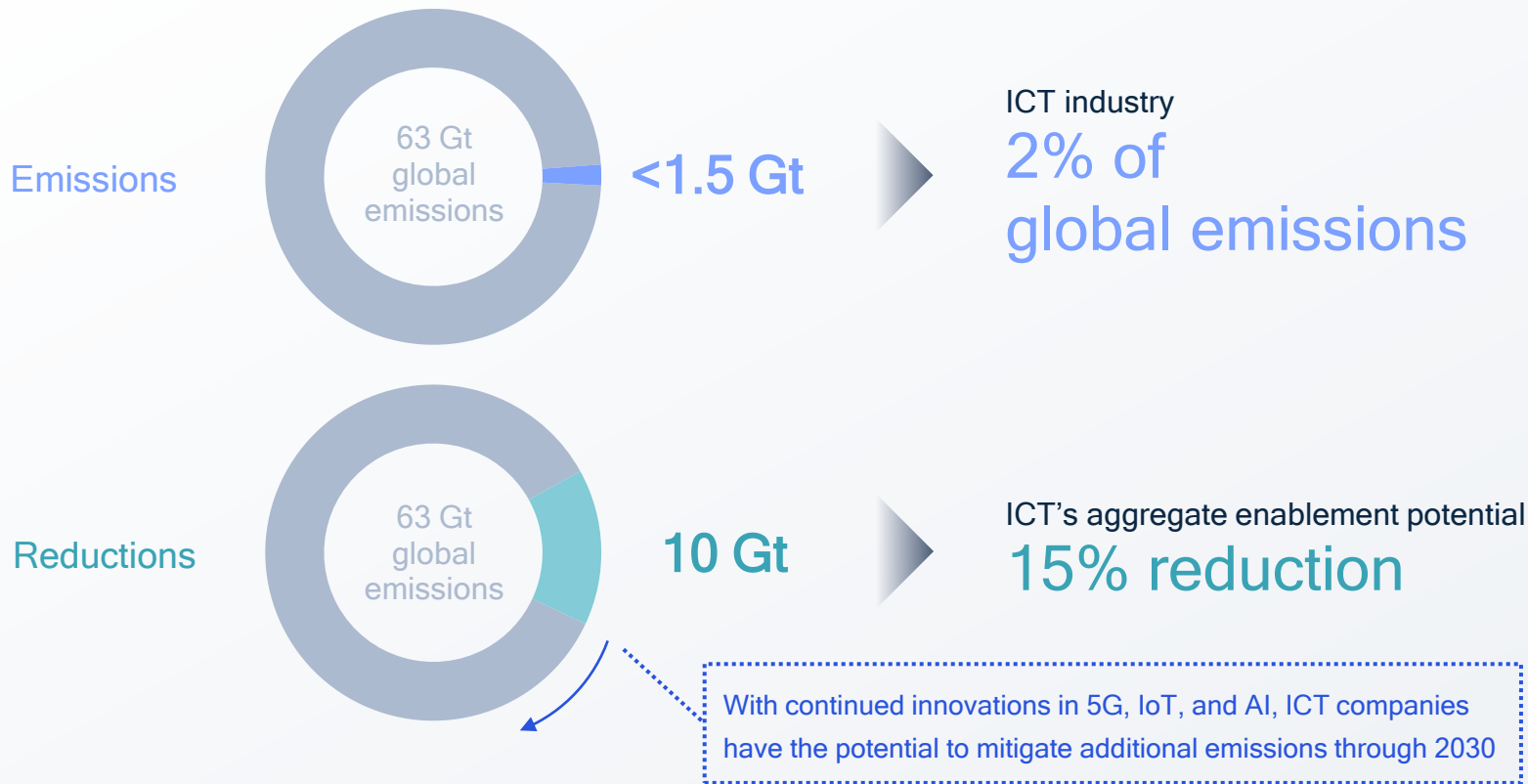


## Environmental

Reducing carbon emissions and enabling sustainable use of energy, water, land, and other natural resources

# Leveraging technology to enable emissions reductions that far exceed the industry's output

Estimated greenhouse gases (GHG) emissions, 2030



The information and communications technology (ICT) industry helps other industries reduce their emissions by

- improving efficiency
- reducing energy use
- offering digital solutions to customers in various sectors

The ICT industry can gain up to \$2 trillion in top-line growth by

- providing sustainability solutions to its customers
- lowering its own energy costs
- improving its reputation and competitive positioning
- increasing customer loyalty and retention



continues to expand globally

265

operators with 5G commercially deployed

275+

additional operators investing in 5G

1B+

5G connections

6B+

5G smartphones to ship between 2020-2026

2,100+

5G devices launched or in development



# Key 5G technologies enabling a more sustainable society



Fixed Wireless  
Access (FWA)



More accessible networks,  
devices, and services



Satellite



Wireless connectivity  
in remote areas



IoT



Smart connectivity for diverse  
devices and services

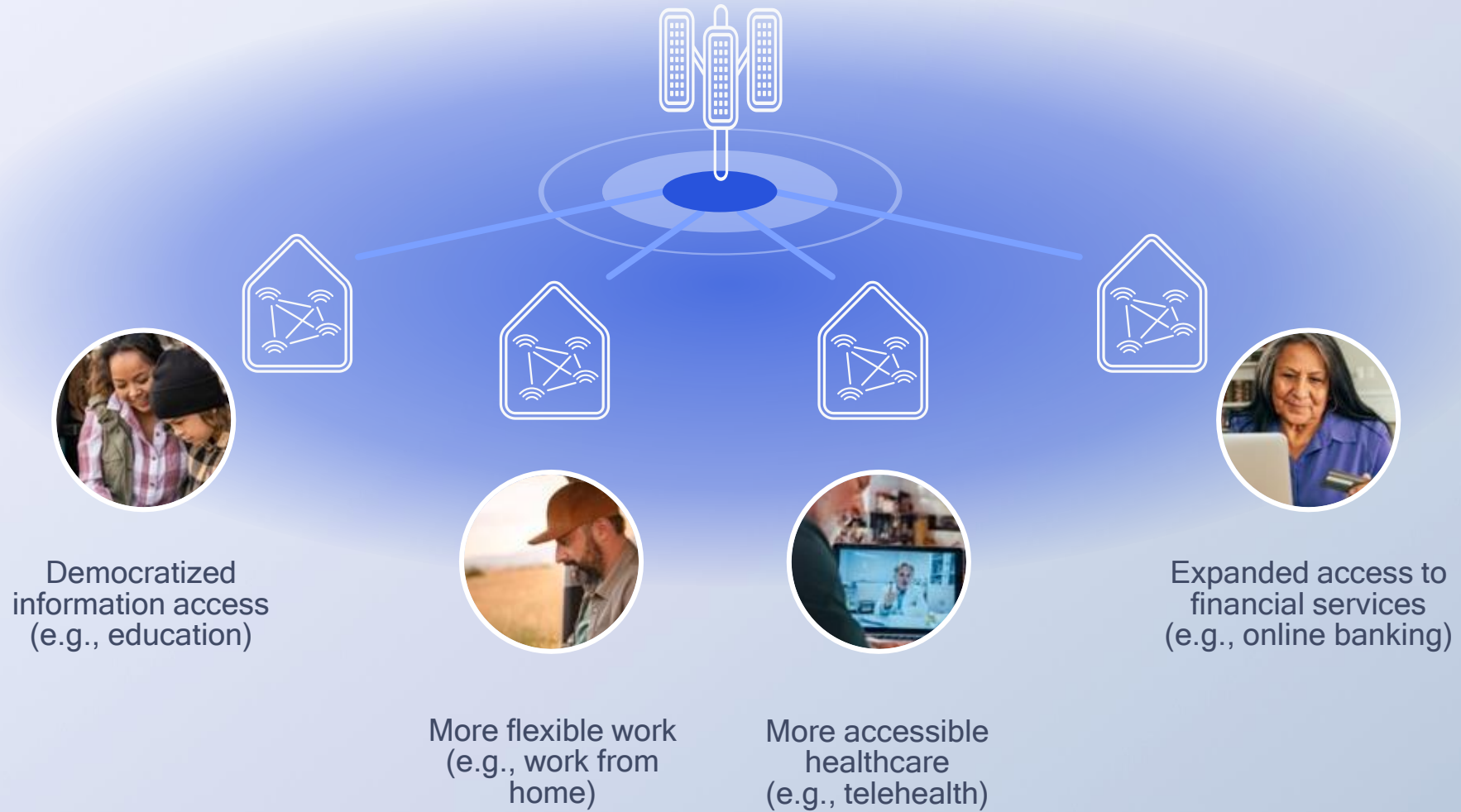


Open RAN



More flexible and  
energy-efficient networks

And more...



**5G Fixed Wireless Access (FWA) can deliver flexible, cost-effective, wireless broadband access**

# 5G FWA has become a cost-effective alternative for fixed broadband

Over 100 service providers around the globe offering 5G FWA

Global 5G FWA connections are expected to triple by the end of 2028 representing 30% of global mobile data traffic



# 5G IoT delivers multiple levels of environmental sustainability benefits

Intelligently connected systems facilitating monitoring, control, optimization and automation



## Smart cities

Smart energy grid  
Optimized water system  
Efficient transportation



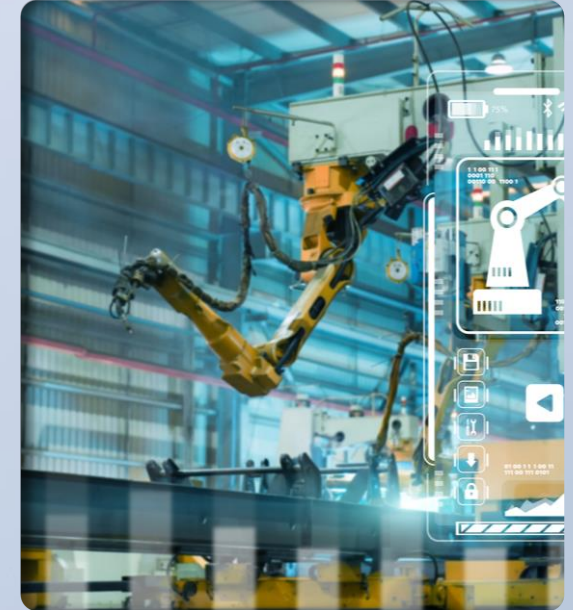
## Smart agriculture

Reduced pesticide use  
Optimized crop yield  
Improved soil health



## Environmental monitoring

Wildfire detection  
Quicker emergency response  
Resilient communication

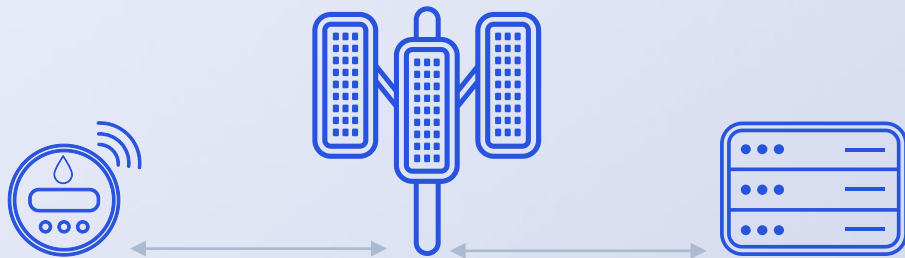


## Efficient manufacturing

Less production waste  
Streamlined logistics  
Opportunity to recycle


# Reducing water consumption and carbon footprint with IoT solutions


Qualcomm, AT&T, Jacobs & Gwinnett County collaboration



The 500-house water monitoring pilot system used a combination of wireless connectivity, smart meters and digital solutions to create performance metrics and alerts that helped the identification of water quality risks and leaks.

Estimated annual benefits of advanced metering infrastructure for a community of 1 million houses

 Almost 500 million gallons of water saved

 GHG emissions avoided equivalent to over 55,000 gallons of gasoline

 Improved water safety

 Lower customer water bills

# The time to act is now

Wireless is an essential enabler for a more sustainable future, delivering more accessible connectivity and services

We continue to invest in purposeful innovation and deliver on our sustainability goals

We're leveraging 5G technology to

Close the digital divide proliferating FWA

Increase economic output expanding IoT

Reduce emissions footprint developing wireless innovations



# 5G Advanced is bringing renewed attention on end-to-end network energy savings

Starting in 3GPP Release 18



### Adding more devices

5G is connecting virtually everyone and everything around us



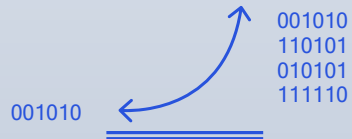
### Introducing new device types

5G is connecting new devices beyond smartphones, e.g., XR, laptops, IoT, and more



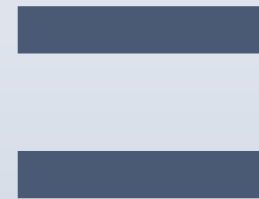
### Growing use cases

5G is expanding to new industries, e.g., industrial, automotive, and more



### Increasing data consumption

Mobile network data traffic grew 36% between Q1 2022 and Q1 2023<sup>1</sup>



More energy consumed

# Further improving power efficiency in wireless networks is essential as device connectivity and data usage increase

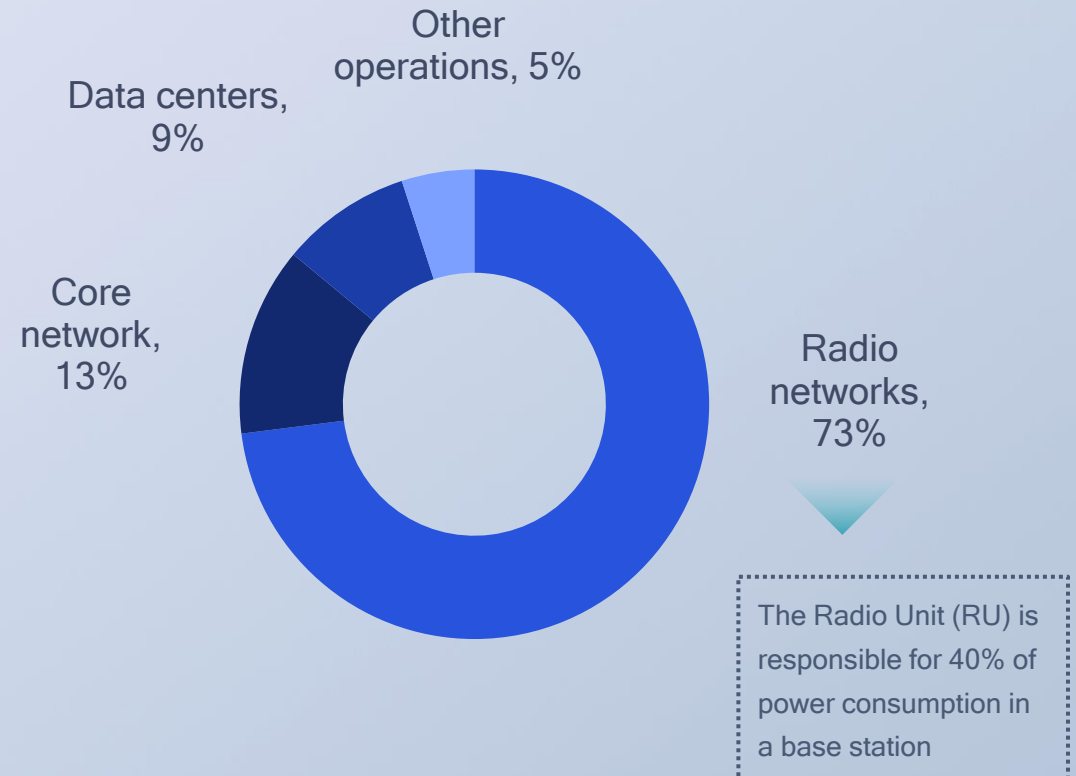
## Radio access network (RAN) consumes the most power in the cellular network

5G network modernization with Open RAN architecture can bring power savings today

Energy consumption constitutes between 20 - 40% of network OPEX<sup>1</sup>

Energy efficiency is a priority for mobile operators

## Mobile operator energy consumption (% total)

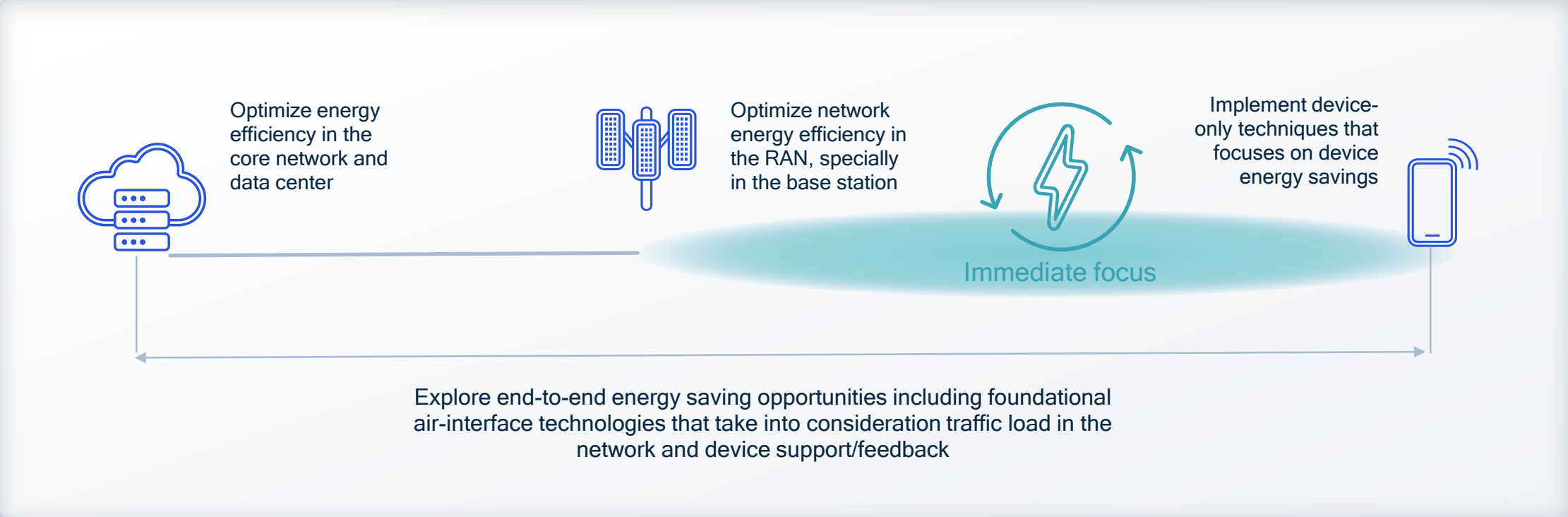


1. GSMA, 2019

Source: Mavenir Whitepaper

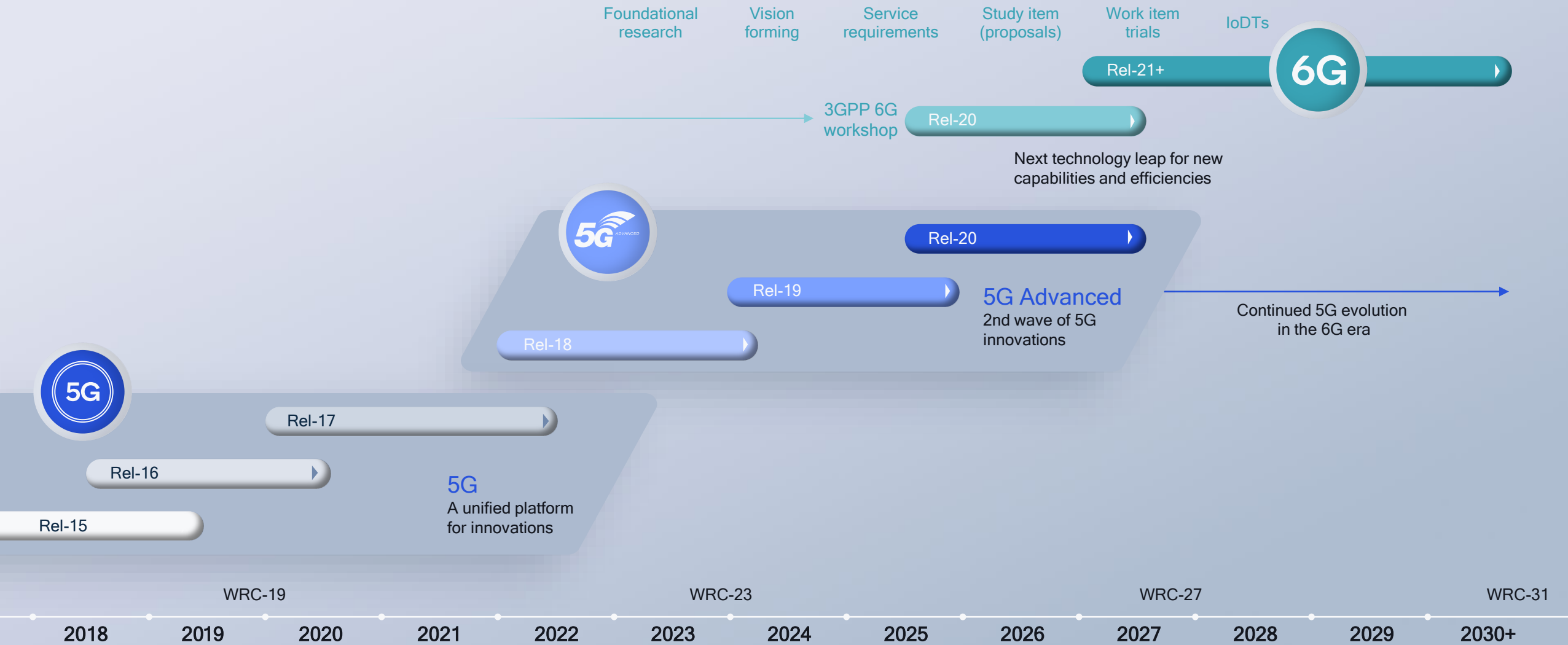
<https://networkbuilders.intel.com/docs/networkbuilders/a-holistic-study-of-power-consumption-and-energy-savings-strategies-for-open-vran-systems-1676628842.pdf>

# Opportunities to reduce energy consumption in a wireless system



Reducing environment impact and operational cost with a greener end-to-end communication system

# Leading the 5G Advanced evolution toward 6G



# Setting the ground for energy efficiency with on-device power savings

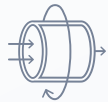
3GPP Release 16

## Introduced innovative on-device power savings techniques



### Wakeup signal (WUS)

A low-power control channel to indicate activity or lack thereof in the corresponding DRX <sup>1</sup> period



### Low-power carrier aggregation control

Efficient activation and deactivation of secondary cell is controlled by the primary cell (i.e., secondary cell dormancy)



### Other power saving techniques

Enhanced cross-slot scheduling, adaptive MIMO layer reduction, low power mode groups, device-assisted power saving, and relaxed radio resource management for low mobility

3GPP Release 17

## Further enhanced on-device power savings



### PDCCH skipping

DCI-based capability that enable a device to reduce the amount of time it spends in monitoring PDCCH <sup>2</sup>



### Search Space Set Group (SSSG) Switching

Enables a device to dynamically switch between a set of SSSGs that is already configured on the active DL BWP of the serving cell



### Paging optimizations

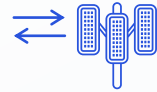
Techniques to reduce unnecessary device paging reception in idle mode



# 3GPP Release 18 sets off the 5G Advanced Evolution



## Strengthen the end-to-end 5G system foundation



Advanced DL/UL MIMO



Enhanced mobility



Mobile IAB, smart repeater



Evolved duplexing



AI/ML air interface



Network energy savings

## Proliferate 5G to virtually all devices and use cases



Boundless extended reality



RedCap evolution



Expanded sidelink



Expanded positioning

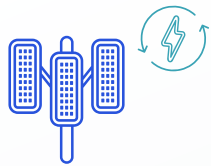


Drones & expanded satellites comm.



Multicast & other enhancements

# Driving towards greener 5G networks



Defining a standardized base station energy consumption model

Including relative energy consumption, sleep states and the associated transition times, and reference parameters



Defining a network energy savings evaluation methodology and relevant KPIs



Studying and developing techniques on the base station and device side to improve network energy savings



System-level studies with various scenarios

Urban micro in sub-6 GHz

mmWave

Urban/rural macro in sub-6 GHz

Dual connected macro

Other scenarios, e.g., small cell deployment

Release 18 scope for network energy savings focus on sustainability and opex reduction

# 5G Advanced introduces new techniques to improve network energy savings



Extending power efficiency innovations to the network

## Release 18



Time domain technique

### Adaptation of DTX/DRX

Define cell DTX/DRX active and non-active cycle and turn off channels or signals in non-active time  
2%-30% energy saving gain<sup>1</sup>



Power domain technique

### PDSCH transmission power adaptation

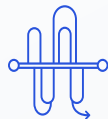
Enhanced CSF to enable UE to send multi-CSI in one CSI report  
Up to 11.5% energy saving gain<sup>1</sup> with throughput reduction of 1.2%



Spatial domain technique

### Adaptation of antenna elements

Enhanced CSF to enable UE to send multi-CSI in one CSI report  
Up to 12% energy saving gain<sup>1</sup> with throughput reduction <2%



Frequency domain technique

### Inter-band carrier aggregation with SSB-less carriers

Define requirements on carrier co-location, receive time difference, and band combo  
>5% energy saving gain<sup>1</sup>



Upper layer techniques

### Mobility and Paging Enhancement

Optimizations for handovers involving network energy saving capable cells and beam management optimizations during paging for FR2



Control Overhead optimization

### On-Demand SSB

Mechanisms enabling an idle mode UE to request SSBs when needed

## Release 19

<sup>1</sup> Analysis is based on the network power model and evaluation methodology defined in TR38.864 for FR1

# Release 18 introduces low-power wake-up signal (WUS) and receiver (WUR) for 5G NR



Identify evaluation methodology for low-power WUS/WUR for lower complexity IoT devices such as industrial sensors, controllers, and wearables



Evaluate low-power wake-up receiver architectures



Evaluate wake-up signal designs to support wake-up receivers



Define L1 procedures and higher layer protocol changes to support the wake-up signals



Evaluate UE power saving gains compared to the existing power saving mechanisms and their coverage availability, latency impact

Studying power saving schemes that do not require existing signals to be used as WUS for power-sensitive, small form-factor devices

# Release 18 further reduce NR RedCap device capabilities



## Further device complexity reduction techniques compared to Rel-17 Redcap devices

- Define just one Rel-18 RedCap device type
- Coexistence of Rel-17 and Rel-18 RedCap and non-RedCap devices in a cell.
- Consider network, device and specification impacts



## Device complexity reduction techniques

- Keep Max RF BW at 20MHz like Rel-17 RedCap
- Reduce baseband operation complexity
- Reduce peak rate to 10Mbps
- Early indication of new device type



## Power saving efficiency enhancements

- Enhanced eDRX in inactive mode

Further expanding the market for RedCap use cases with relatively low cost, low energy consumption, and low data rate requirements

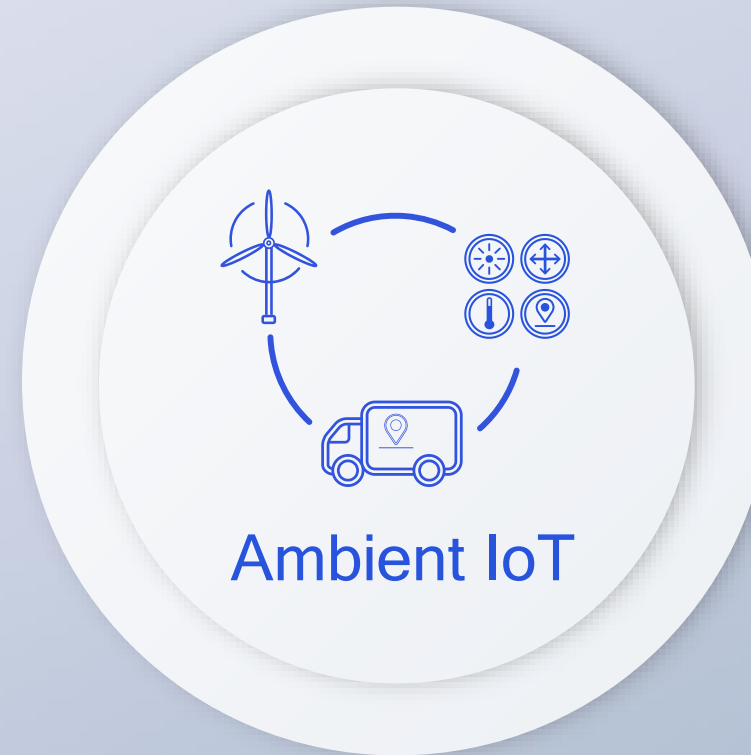
# 5G Advanced

## Further scaling down 5G IoT support

Enabling a more energy efficient solution for low complexity IoT devices

**Device type**  
Supporting ultra-low complexity devices with ultra-low power consumption

**Energy storage**  
Device powered by energy harvesting, either battery-less or with limited energy storage (e.g., using a capacitor)

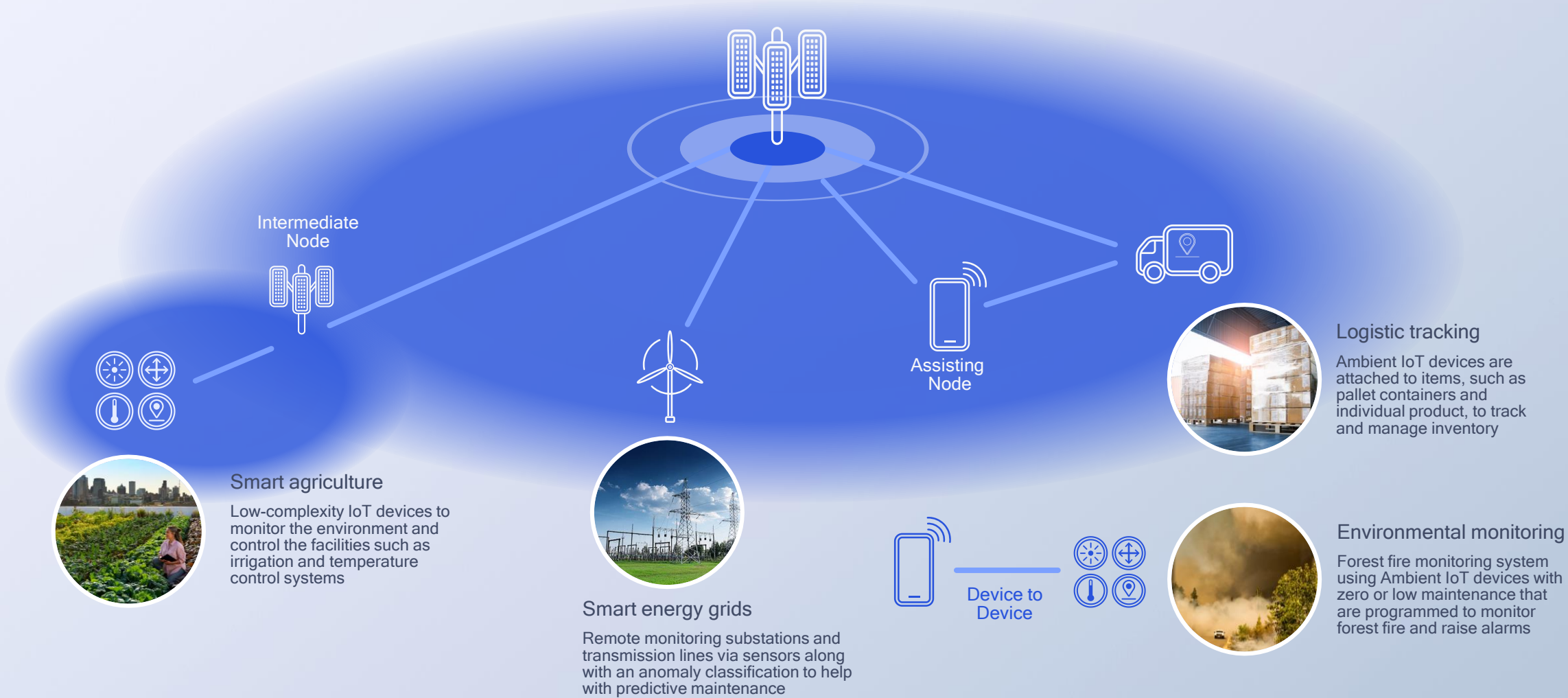


**Maintenance level**  
Targeting to be maintenance-free and to have long field lifespan (e.g., more than 10 years)

**Deployment scenarios**  
Flexible communication mode (e.g., direct or indirect), location (e.g., indoor or outdoor), and use cases (e.g., sensors, positioning, ...)

3GPP Rel-19  
SA1 study & work items

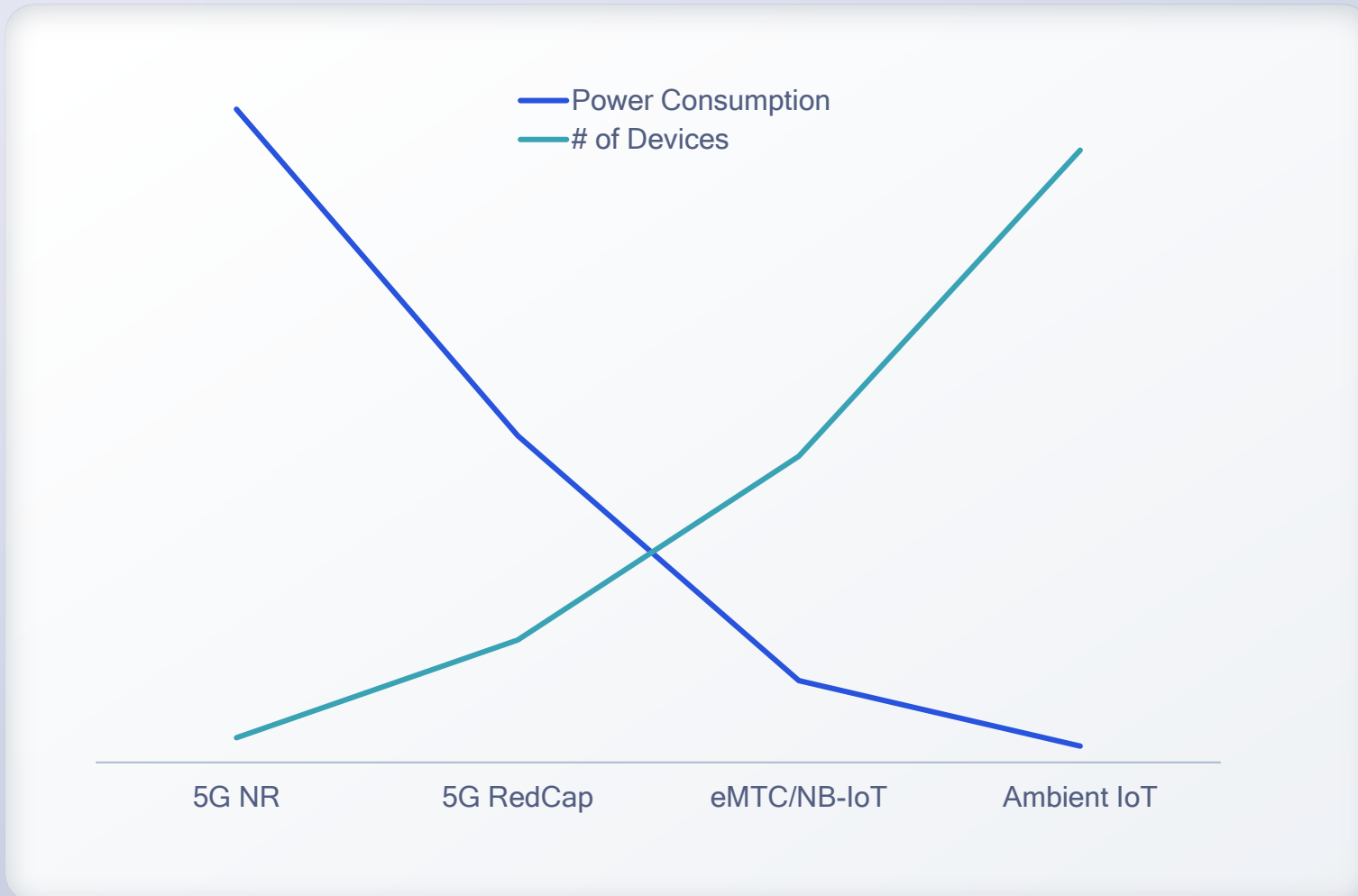
3GPP Rel-18  
RAN study item



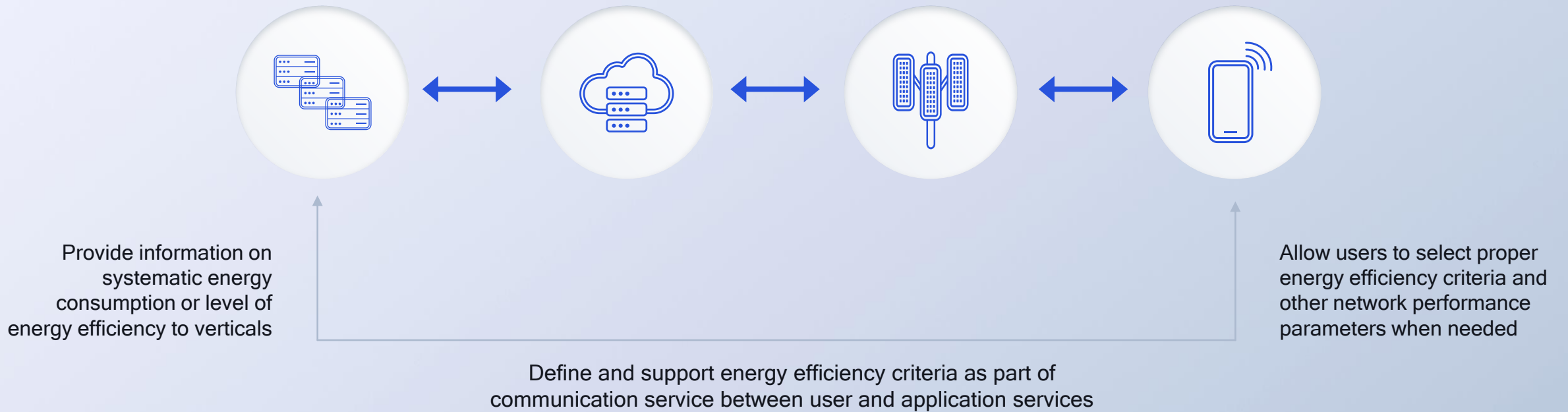
**Ambient IoT enables diverse use cases that require devices with zero or low maintenance capabilities**

Flexible architecture supporting direct and/or indirect connectivity requirements

# Power Consumption vs. Device Density



Ambition to connect virtually everything, everywhere requires a more scalable, sustainable network solution



## Enabling energy efficiency as a service in Release 19

End-to-end approach to adjust network resources based on different energy modes of applications



Qualcomm

We're pioneering foundational research for  
a greener next-gen wireless design

Targeting unparalleled system efficiency



Key market trends and technology drivers

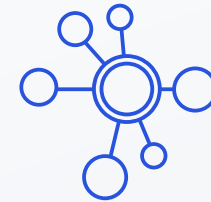
# leading the way to 6G



Core technology  
advancements



Social, economic, and  
environmental sustainability



Enhanced and  
new experiences

# Key sustainability pillars leading the way to 6G

Social,  
economic, and  
environmental  
sustainability



More accessible networks, devices, services to promote digital equality



Wireless connectivity everywhere to fuel sustained global economic growth



Wireless system design to consciously minimize environmental impact

Along with other industry leaders

# We are actively driving global green initiatives with next-gen wireless

NEXT G  
ALLIANCE

United States  
NextG Alliance



European Union  
EU-funded R&D



China  
IMT-2030 PG



Japan  
Beyond 5G PC

Bharat 6G  
Alliance

India  
Bharat 6G Alliance

South Korea  
6G National Strategy

## Global Momentum for 6G is growing

We are leading key discussions and working groups to promote early government investments in critical technologies



IMT-2030 defines next-generation mobile system requirements for 2030 and beyond



The standards body responsible for global 6G technology standardization

# Evolving towards a more dynamic energy-efficient wireless system

## On-device energy savings

INDEPENDENTLY AT THE DEVICE



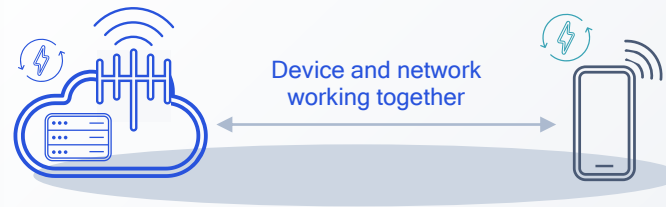
On-device power savings by optimizing existing functions

Rel-16 introduced techniques such as wakeup signal (WUS) and enhanced carrier aggregation

Rel-17 optimized paging operations in idle mode and reduced PDCCH monitoring time in connected mode

## Network energy savings

COORDINATED BETWEEN DEVICE AND NETWORK



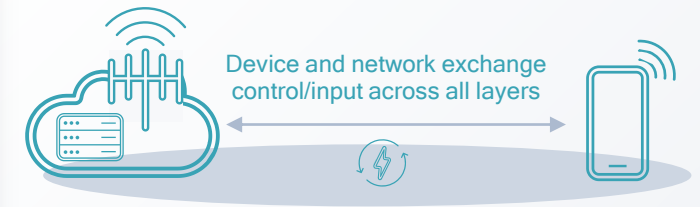
Shifting focus to network-side savings and continuing to optimize device power consumption

Rel-18 further enhanced device energy efficiency for XR and RedCap; Rel-19 may further enhance low-complexity IoT with WUS/WUR

Rel-18/19 focuses on new network energy saving techniques in the time/freq/power/spatial domains

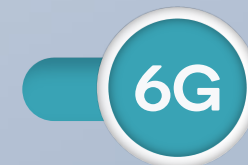
## Native E2E energy savings

AT ALL DEVICE AND NETWORK LAYERS



Device and network energy optimization across all protocols and layers

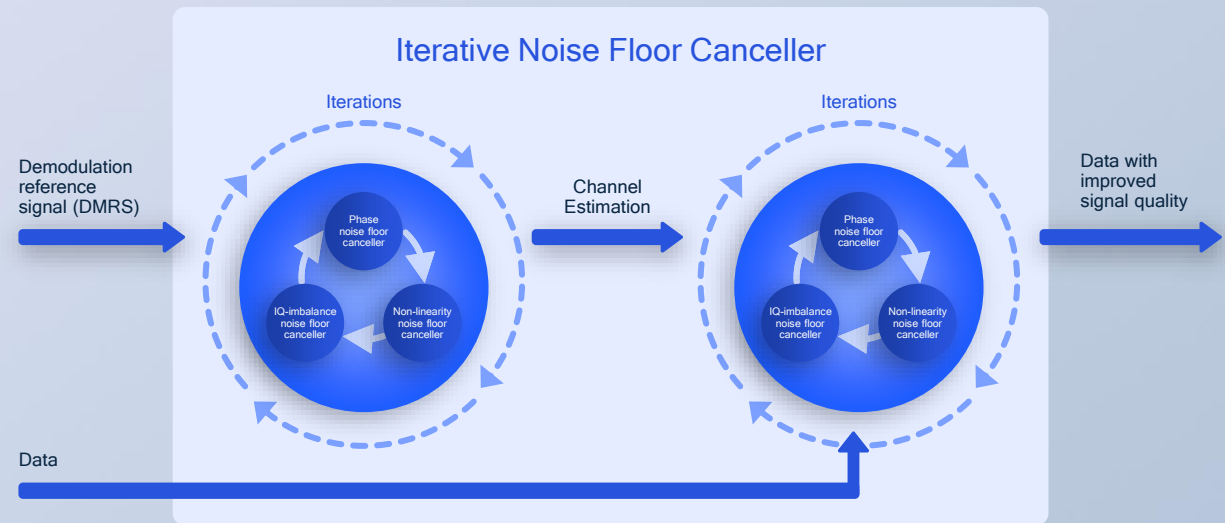
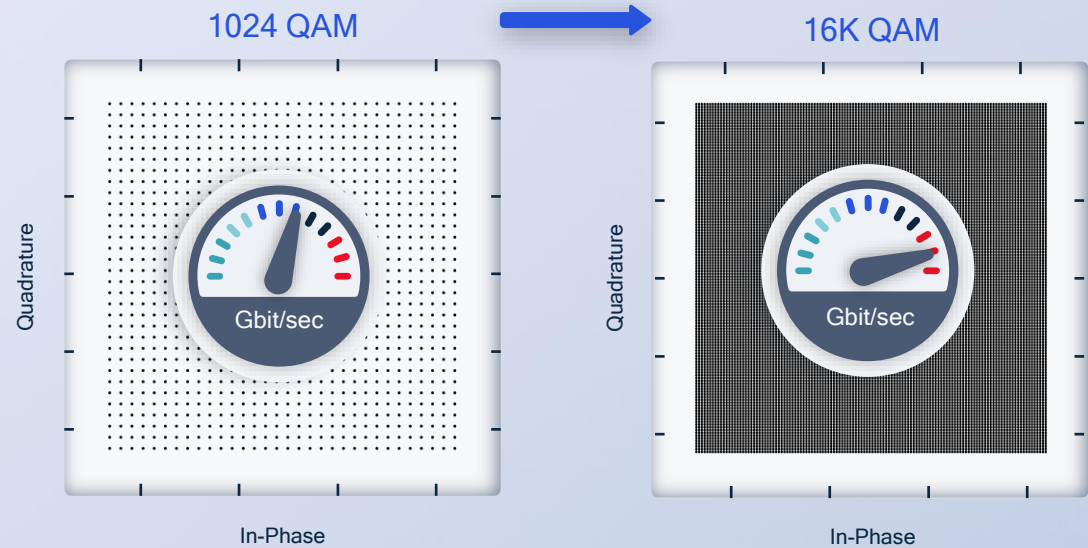
Continuing to improve and balance end-to-end system performance/energy efficiency tradeoffs (e.g., MIMO, mobility, power amplifier efficiency, distributed topology, and others), as well as deployment complexity and performance



# Super Quadrature Amplitude Modulation (QAM)

Enabling a significant increase in speed and lower energy usage

Reducing the noise in the receiver in an iterative fashion to incrementally improve the signal quality

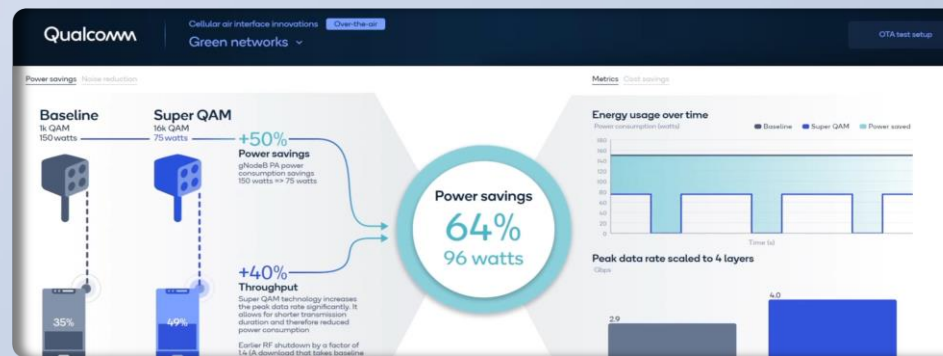
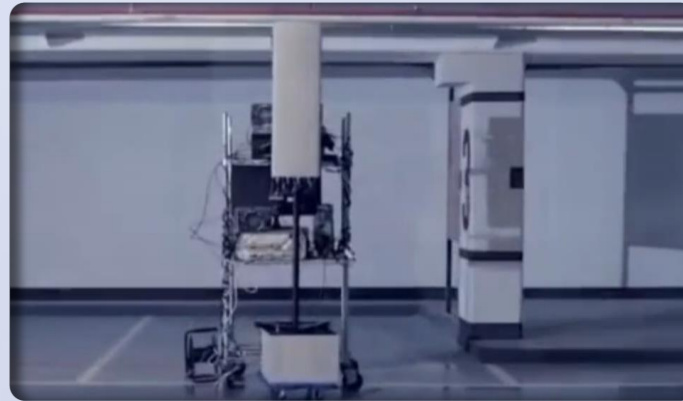
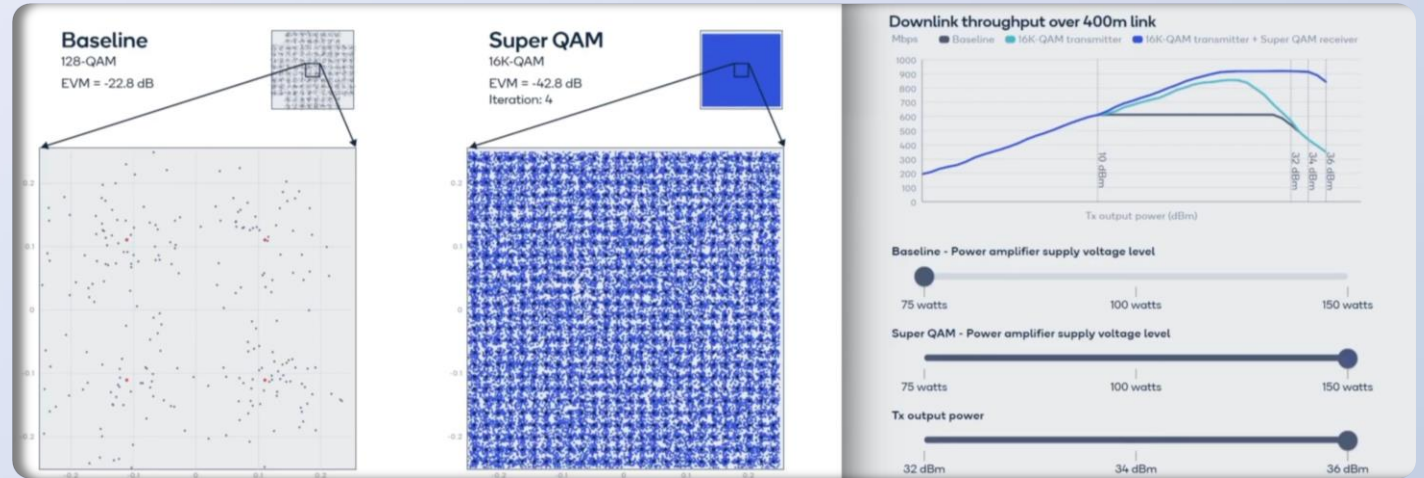


# Greener and more sustainable networks

Improving system efficiency with super-QAM

Using our OTA testbed, we prototyped a noise-canceling method that works iteratively to achieve a high degree of modulation (e.g., 16k-QAM for sub-7 GHz)

Our super-QAM demo enables the network to operate its PA at the optimal operating point, balancing power savings and increased speeds in real-world conditions



# A smarter wireless platform to support enhanced services and new use cases

6G will continue to support existing services in previous generations



# 5G Advanced

The path toward a  
more sustainable future



Advanced wireless innovations are the catalysts for a more connected, efficient, and sustainable world



5G Advanced's system optimizations set the stage for a greener next-generation wireless design



We are driving foundational system research that targets unprecedented levels of efficiency and performance

# Thank you

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