Qualcomm San Diego, CA January 2023

How 5G is enabling resilient communication for the connected intelligent edge

Delivering end-to-end 5G system security at scale

@QCOMResearch

Todays Agenda

1

Resilient communication requires an end-to-end approach to system security

2

5G already delivers strong security today with focused enhancements coming in 5G Advanced and beyond

3

Zero-trust security is at the core of a resilient system, for 5G to deliver a wide range of services

4

We have a robust chipset security portfolio and are leading the way in realizing new features and services

5

Questions?

Our presenters

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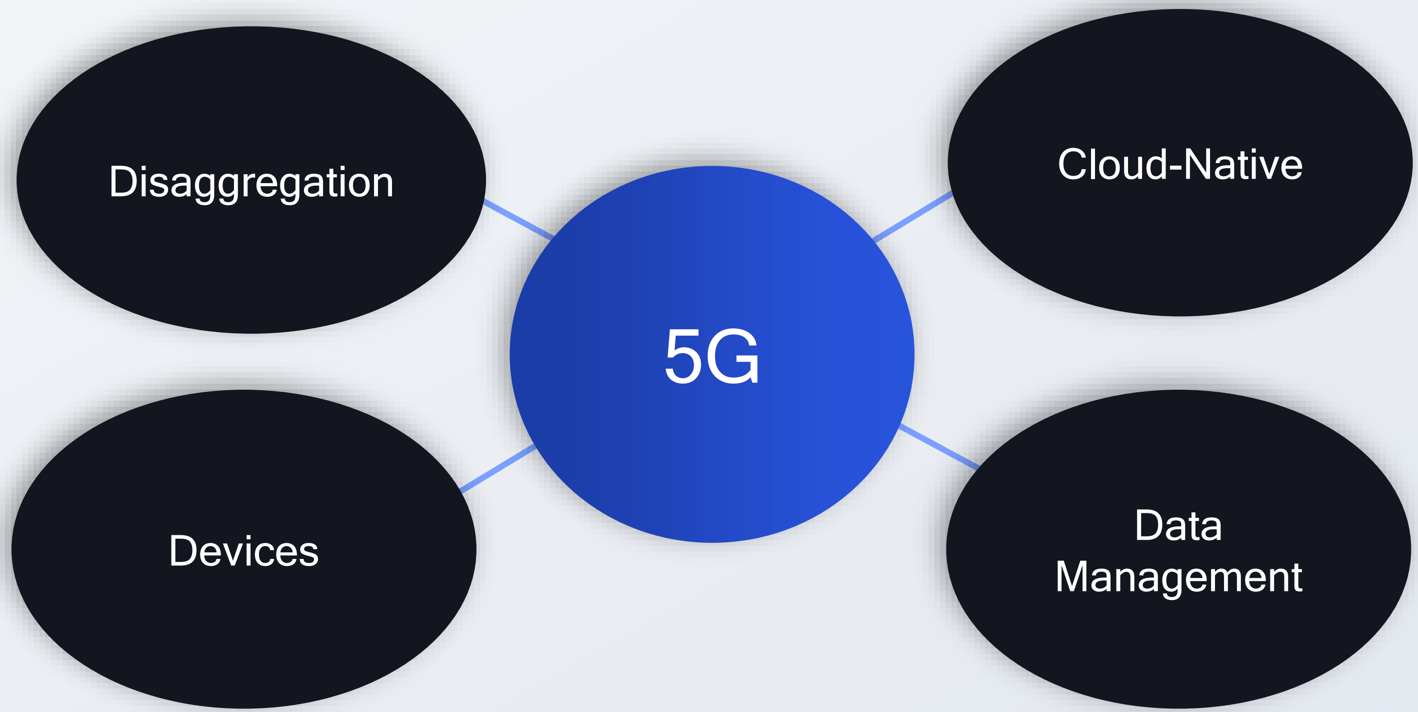
5G Security Considerations



Source: Heavy Reading

5G Accelerating Globally

225+
Operators with 5G commercially deployed

275+
Additional operators investing in 5G

1B+
5G connections by 2023 – 2 years faster than 4G

5B+
5G smartphones to ship between 2020 and 2025

1,490+
5G designs launched or in development

Sources – 5G commercial networks, operators investing in 5G: GSA, Sep ‘22. 2023 5G connection projections: average of ABI (Sep ‘21), Ericsson (Jun ‘21) and GSMA Intelligence (Sep ‘21). 5G cumulative smartphone shipments: average of CCS Insight (Sept ‘21), Counterpoint Research (Dec ’21), IDC (Nov ‘21), Strategy Analytics (Oct ‘21); Launched / announced devices: GSA, Sep ’22.

Transportation

Manufacturing

Industrial

Retail

Energy

Driving digital transformation across industries

5G will enable $13.1 Trillion in global sales activities in 2035

Agriculture

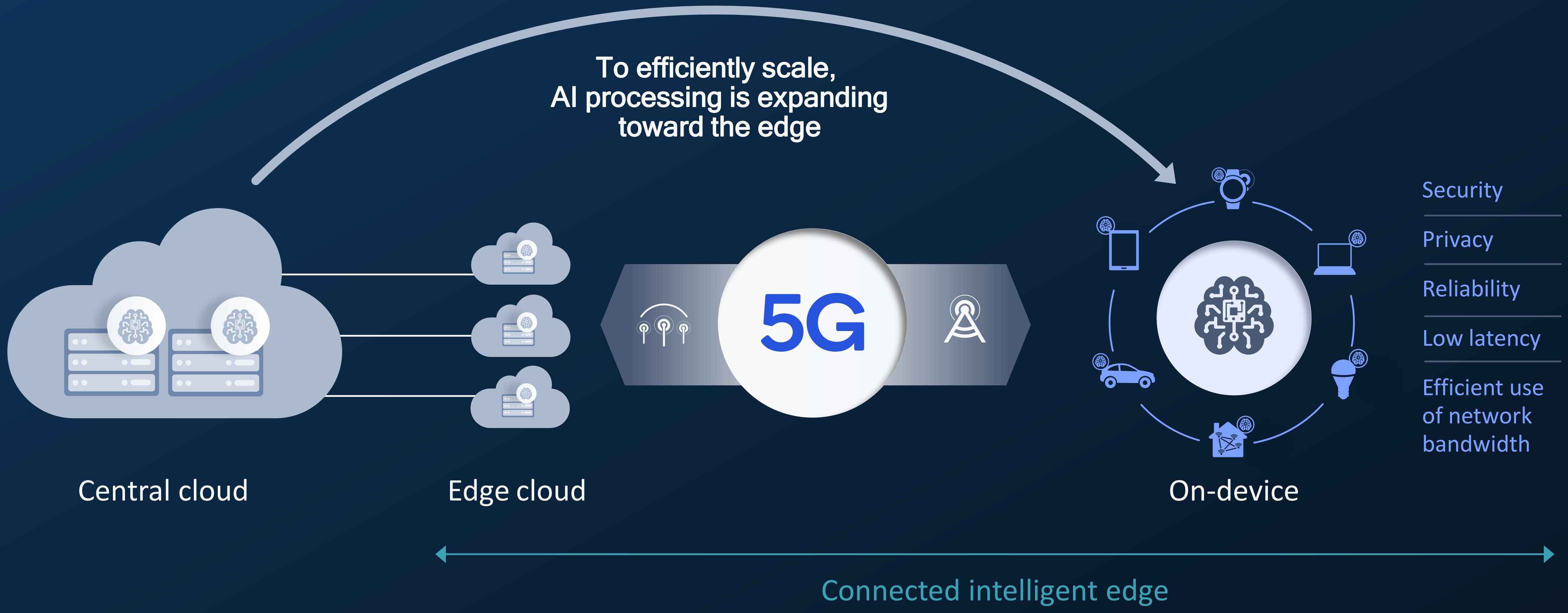
Healthcare

Public safety

Smart cities

Entertainment

Source: The 5G Economy, an independent study from IHS Markit,
commissioned by Qualcomm Technologies, Inc., November 2020



Leading the realization and expansion of the connected intelligent edge

Convergence of:

- Wireless connectivity
- Efficient computing
- Distributed AI

Unleashing massive amount of data to fuel our digital future

Connected intelligent edge expansion

leading to greater threat surface

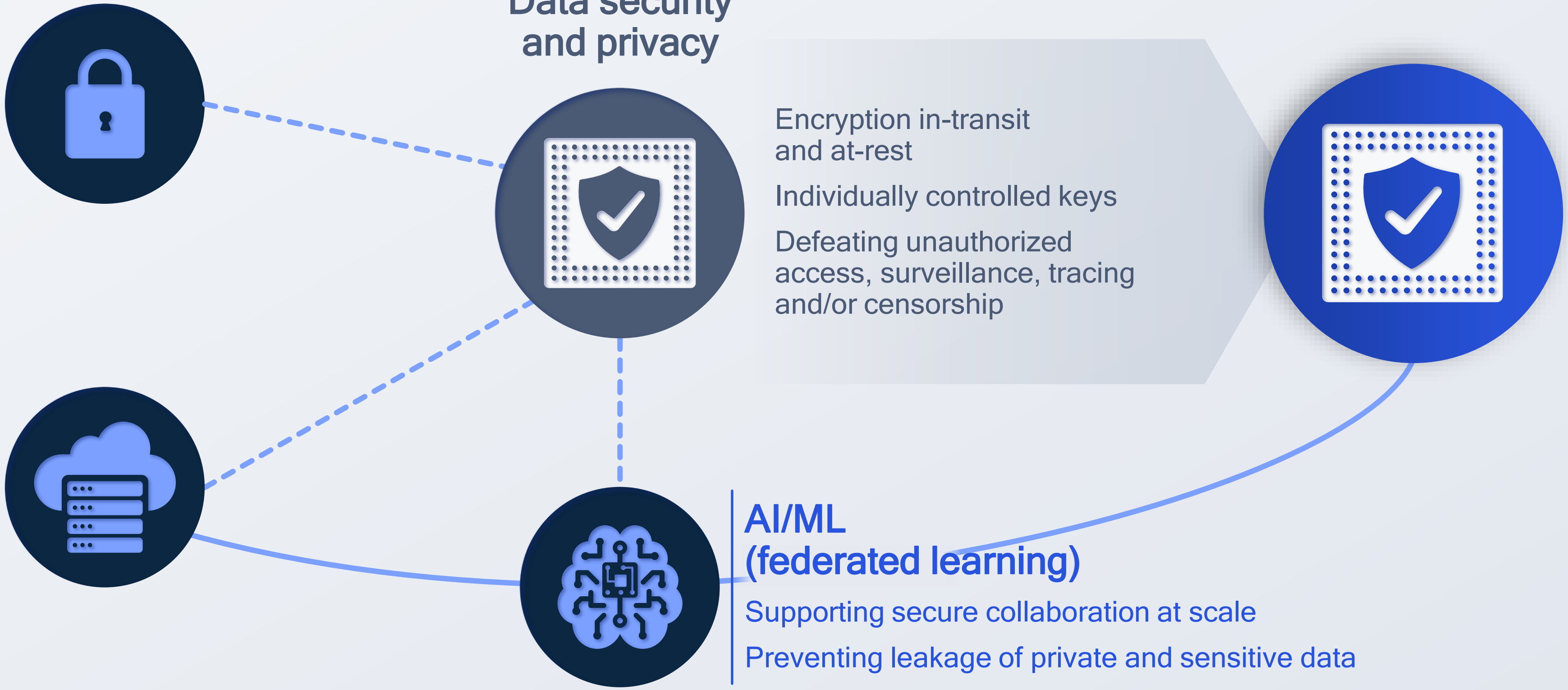
in the end-to-end system

More devices are connected across different deployments (i.e., public and private networks)

Networks are becoming more disaggregated with increasing number of interfaces

5G system continues to evolve to address growing security and privacy needs

Protecting data – the most valuable asset in the digital world



Data provenance

Data authenticity and origin proof

Single version of facts

Data collection and processing

Secure collection and storage of data

Secure and trusted processing of data in the cloud

Privacy-preserving computation leveraging Confidential Computing Architecture (CCA) and Homomorphic Encryption (HE)

Data security and privacy

Encryption in-transit and at-rest

Individually controlled keys

Defeating unauthorized access, surveillance, tracing and/or censorship

AI/ML (federated learning)

Supporting secure collaboration at scale

Preventing leakage of private and sensitive data

Data is exposed to various security and privacy threats

In transit | At rest in local and/or remote storage | In use (processing) | In access | For validation

Data protection regulations

Impose explicit compliance for security, integrity, and confidentiality

Canada
Digital Charter
Implementation Act

United States
California Consumer
Privacy Act (CCPA)

Europe
General Data Protection
Regulation (GDPR)

China
Personal Information
Protection Law (PIPL)

Nigeria
Nigeria Data Protection
Regulation (NDPR)

India
Upcoming Personal Data Protection
Bill (PDPB) based on the GDPR

Brazil
Lei Geral de Proteção
de Dados Pessoais
(LGPD)

Australia
Australia's Privacy Act

15+

Countries with
GDPR-like
Data Privacy Laws

GDPR[1] principle for integrity and confidentiality → Processing must be done to ensure appropriate security, integrity, and confidentiality (e.g., by using encryption)

[1] General Data Protection Regulation

Resilient communication requires an end-to-end approach to system security

5G System strives for resilient communication

End-to-end approach to provide comprehensive system security and privacy

Communication Resiliency

Privacy

Data encryption on all levels

Security

Integrity, reliability, and protection of networks, devices, applications, and services

Identity

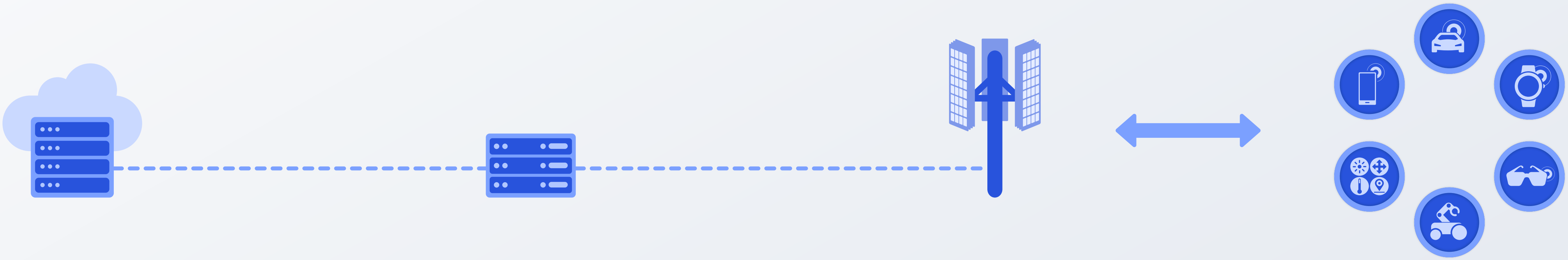
Encrypted long-term subscriber identifiers

Trust

Mutual authentication and authorization

Robustness

Attack detection and confinement, and sustained operations



Application Threats

App server vulnerabilities

Application vulnerabilities

API vulnerabilities

IoT vulnerabilities

Core Network Threats

DoS[1] & DDoS[2] attacks

Sniffing

API vulnerabilities

Roaming partner vulnerabilities

Improper access control

IoT vulnerabilities

Radio Network Threats

Jamming

MitM[3] attack

Rogue nodes

User privacy

Eavesdropping

DoS attacks

Device Threats

Malware

Sensor susceptibility

API vulnerabilities

Bots DDoS

Firmware hacks

Device tampering

Why resilient communication requires an end-to-end solution

An end-to-end security approach is required to provide wide-ranging protection to the dynamic attack surface

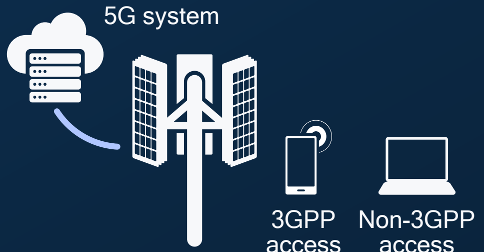
1 Denial of Service; 2 Distributed Denial of Service; 3 Men in the Middle

5G is the most scalable and trustworthy wireless connectivity platform yet

5G

Delivering enhanced level of wireless security

Release 15 is built on the proven, solid security foundation of 4G LTE



Flexible framework

To support new devices, use cases, and deployments

Unified authentication for 3GPP/non-3GPP devices

Security anchor function

Network slicing

Tighter security

To expand protection and increase flexibility

User-plane integrity protection

Lower trust in serving networks

Subscription credentials in secure HW element

Enhanced privacy

To eliminate communication of unprotected device-specific info

Ciphered user and device specific information

Providing a flexible framework to secure a wide range of deployments

Sidelink

Secure group member and service discovery

Flexible configuration of security and privacy per application

V2X

Sidelink groupcast and broadcast security

Sidelink unicast security including bearer layer security and privacy

Edge

End-to-end security between the device and edge server

Support for server-authenticated TLS

Private Networks

As another layer of security, 5G network slicing can be leveraged to provide traffic segregation between various business

Device onboarding support

IoT

Control and user planes security optimizations to support massive IoT

5G System modeled as a bridge in Time Sensitive networks (TSN) to support private networks in IIoT

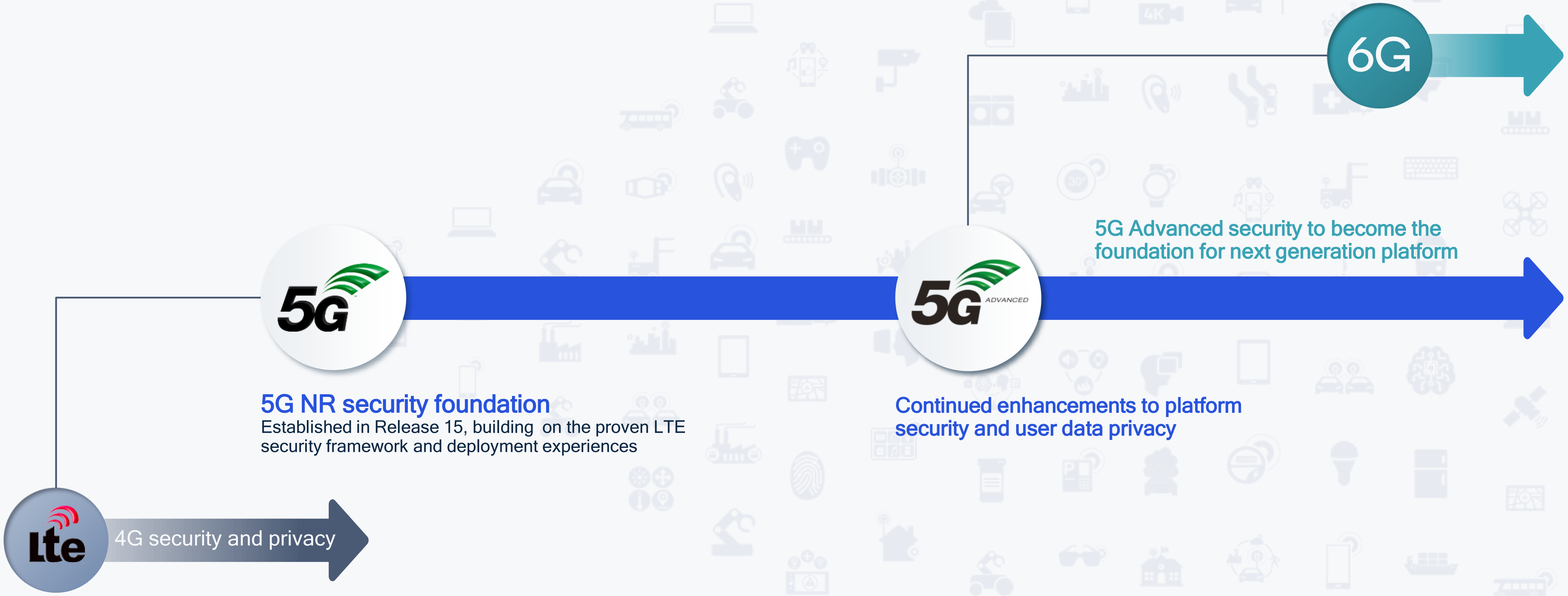
Secure credentials and identifiers

Secure transport in both radio and core networks

Flexible policy frameworks and security monitoring

5G already delivers strong security today

With focused enhancements coming in 5G Advanced and beyond



4G security and privacy

5G NR security foundation

Established in Release 15, building on the proven LTE security framework and deployment experiences

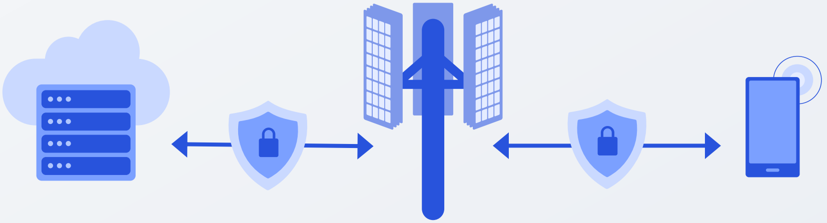
Continued enhancements to platform security and user data privacy

5G Advanced security to become the foundation for next generation platform

Continued evolution to strengthen the mobile security foundation

5G Security

Release 15



5G security foundation

Release 15

Focusing on end-to-end system security for eMBB use cases (e.g., smartphones)

Flexible, unified, and strong subscriber authentication

Supporting

- Various mutual authentication protocols (i.e., 5G-AKA[1], EAP-AKA', and EAP-TLS[2]) and non-SIM authentication for non-public networks and IoT devices
- Unified procedures for 3GPP and non-3GPP access
- Secondary authentication and authorization for data network access

Enhanced subscriber privacy

Providing encryption for long-term subscriber identifiers via Subscription Concealed Identifier (SUCI)

Secure service-based architecture (SBA)

Supporting TLS 1.2/1.3 to protect transport layer communication and OAuth[3] 2.0 to ensure service access only to authorized network functions

Secure roaming interconnects

Introducing SEPP[4] at the application layer to provide communication protection in interconnect networks

User-plane integrity

Introduced for 5G NR standalone with the flexibility of reduced data rate

3GPP Release 15 established the security foundation for 5G

1 Authentication and Key Agreement; 2 Extensible Authentication Protocol - Transport Layer Security; 3 Open Authorization; 4 Security Edge Protection Proxy

5G Security

Release 16

5G security foundation

Release 16

Enhancing security for non-public networks, IoT, commercial use cases and beyond

Use case-specific security enhancements

Ensuring security and privacy for cellular IoT, V2X, URLLC services, and integrated access backhaul (IAB)

Specific network slice authentication and authorization

Providing separate authentication and authorization per network slice

Secure non-public networks

5G private networks provide security and privacy on dedicated resources that are independently managed

Inter-PLMN user plane security

The role of the User-Plane Function (UPF) is expanded to include traffic protection with a common firewall between two roaming PLMNs

Full-rate user plane integrity protection

No rate limitation allowing a receiver to determine that received messages are not tampered with by an attacker

Secure industrial IoT

Expanding TSN[1] support for time synchronization and time-sensitive communications (TSC) for applications, along with the corresponding security mechanisms (i.e., secure interfaces, authentication and authorization)

Improving 5G system resiliency for broader devices, use cases, verticals

[1] Time Sensitive Networking

5G Security

Release 17

5G security enhancements

Release 17

Improving security for sidelink, drones and broadcast systems

Secure unicast, multicast and broadcast applications

Protecting both user and control planes

Secure proximity-based services

Providing security for sidelink communications (i.e., security for direct discovery, direct communications, and relay communications)

User consent framework

Establishing a framework for privacy control of user data collected by the network

Security for drones

Ensuring security and privacy for unmanned aerial systems (UAS)

Improved edge security

Supporting security between UE and AF

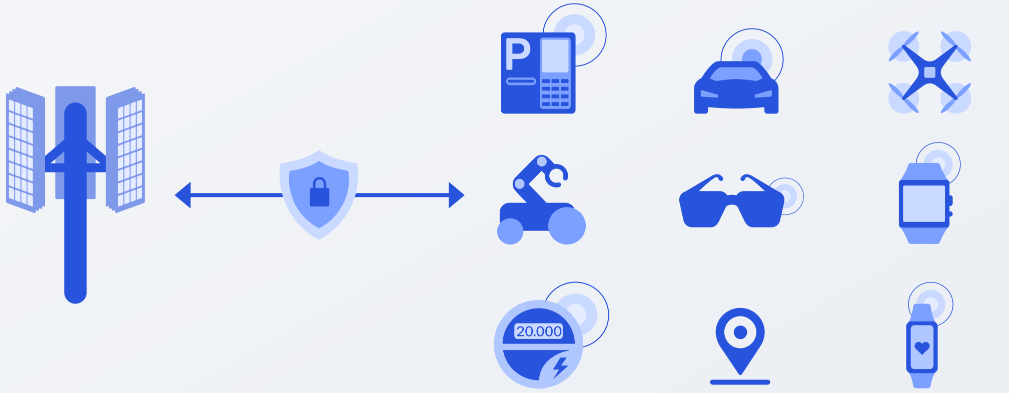
Secure enablers for network automation (eNA)

Securing data collection and analytics for network automation – including AI/ML

Strengthening system security for new 5G communication modes

5G Security

Release 18+



5G advanced security enhancements

Release 18+

Expanding to new devices, use cases, deployments

Sidelink positioning and ranging security

Protecting both user and control planes

AI/ML security

Securing AI/ML model and data to ensure the robustness of AI/ML in 5G system

Security enhancements against false base stations

Continued efforts from Rel-16 to identify and address potential threats from false base station

Identity privacy

Securing data collection and analytics for network automation - including AI/ML

Personal IoT network security

Securing access to a personal IoT network and its communication

Continued enhancements for new use cases & deployments this decade

And establishing the security foundation for next-generation mobile platform

Key longer-term research vectors enabling the path towards 6G

AI-native E2E communications

Scalable network architecture

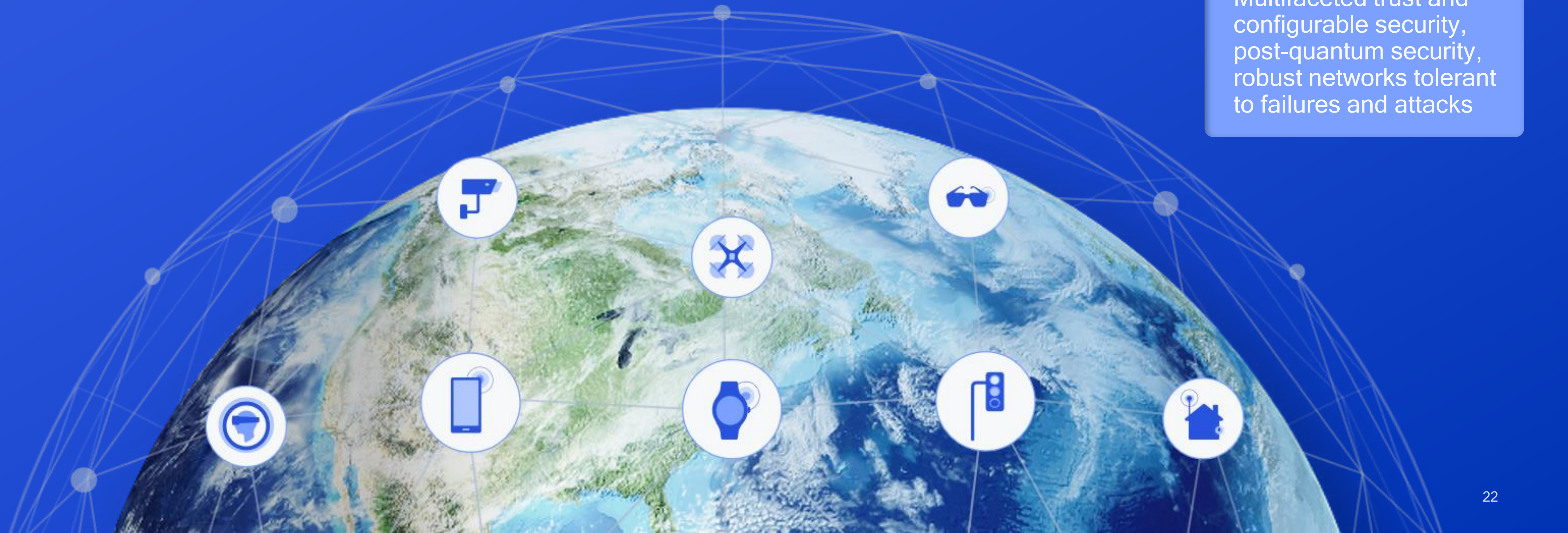
Expanding into new spectrum bands

Merging of worlds

Air interface innovations

Communications resiliency

Multifaceted trust and configurable security, post-quantum security, robust networks tolerant to failures and attacks



Our research focus in 6G communications resiliency across all layers

A continuous end-to-end approach to system security and data privacy

Native security

- Security across all layers
- Service adaptive security
- Cloud-native security architecture

Post-quantum security

- Post-quantum crypto algorithms
- Quantum security (QKD, QRNG)

Data security and privacy

- AI/ML security
- Confidential computing
- Homomorphic encryption

Robust trust

- Multifaceted trust
- Zero-trust architecture
- Verifiable root of trust

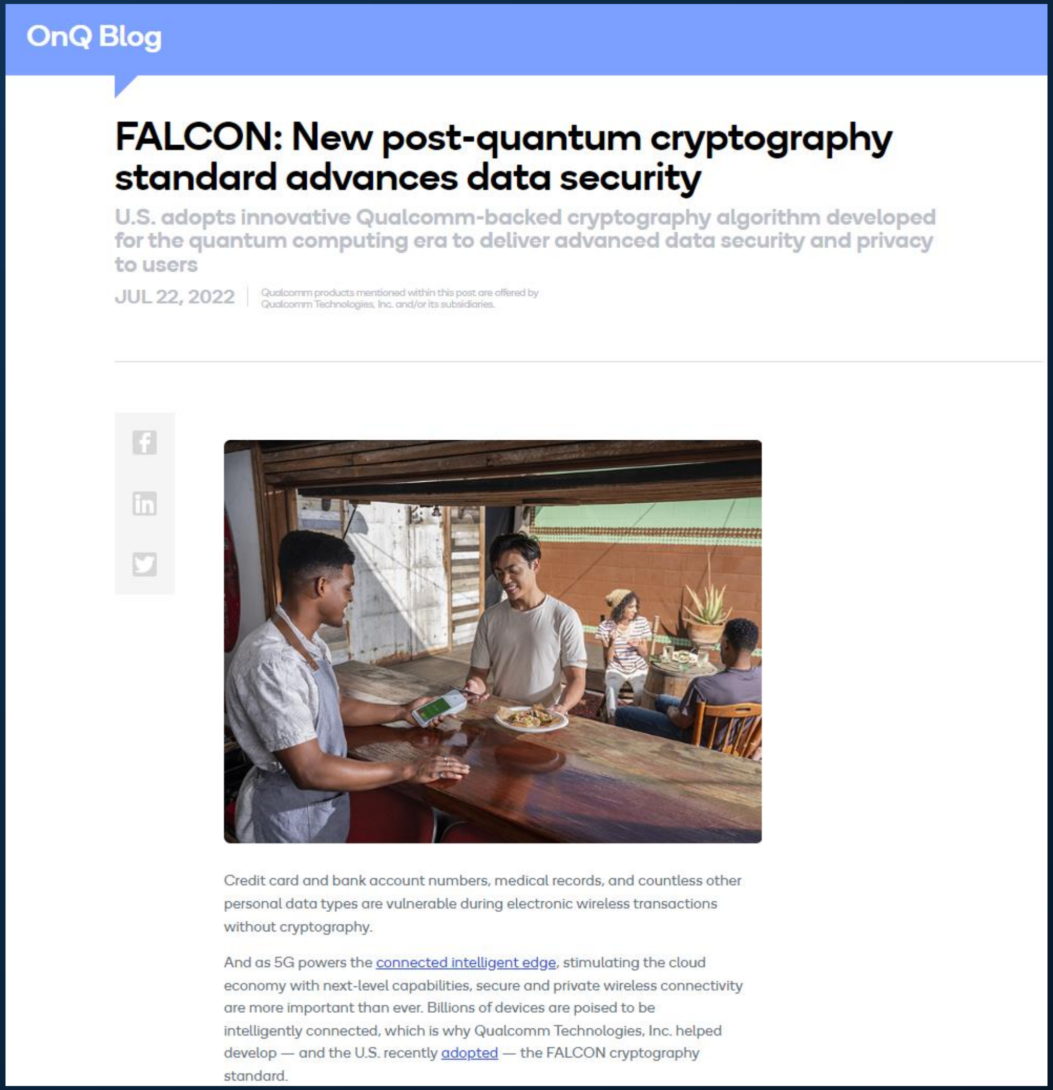
Other key research areas

- Jamming resilience
- Generative adversarial network
- Ultra secure communication
- Web 3.0
- Differential privacy
- Remote attestation
- Secure multi-party computation
- Blockchain
- Confidential computing architecture
- Physical layer security
- Data ownership structure/ management
- Secure device onboarding
- Deep fake protection
- Homomorphic encryption

Our research is driving advanced cryptography standard for the quantum computing era

FALCON – a post-quantum digital signature algorithm – delivers advanced data security to users

Designed to offer superior protection, compactness, speed, scalability, and memory economy



OnQ Blog

FALCON: New post-quantum cryptography standard advances data security

U.S. adopts innovative Qualcomm-backed cryptography algorithm developed for the quantum computing era to deliver advanced data security and privacy to users

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Credit card and bank account numbers, medical records, and countless other personal data types are vulnerable during electronic wireless transactions without cryptography.

And as 5G powers the connected intelligent edge, stimulating the cloud economy with next-level capabilities, secure and private wireless connectivity are more important than ever. Billions of devices are poised to be intelligently connected, which is why Qualcomm Technologies, Inc. helped develop — and the U.S. recently adopted — the FALCON cryptography standard.

Learn more:

Zero-trust security is at the core of a resilient system

Zero trust security model

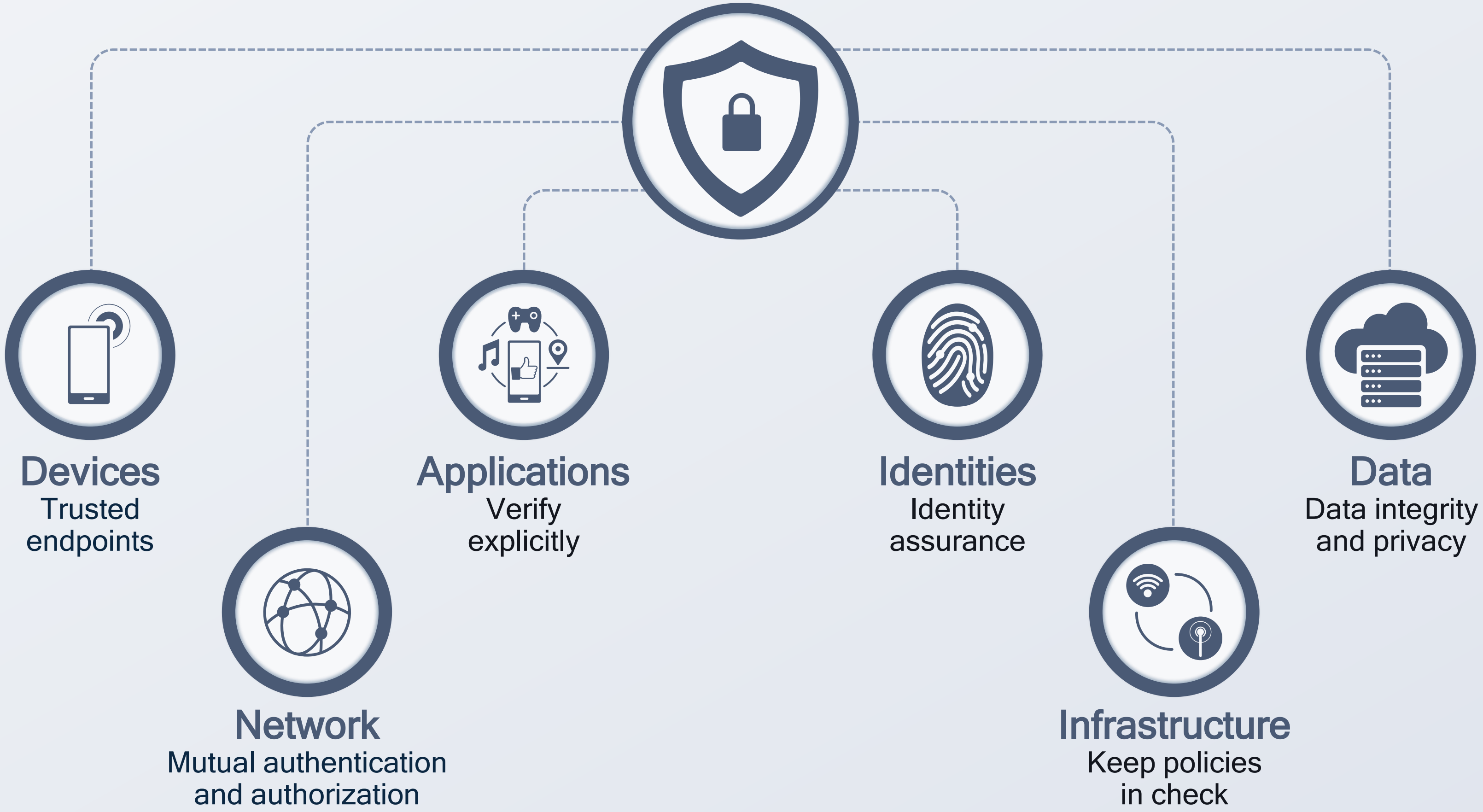
moves defenses from static, network-based perimeters to focus on users, assets, and resources

“Never trust, always verify”

approach to security, both inside and outside of the network

Zero Trust Security Model

Built on web protocols utilizing virtualization, containerization, and cloud-based platforms



Devices
Trusted endpoints

Network
Mutual authentication and authorization

Applications
Verify explicitly

Identities
Identity assurance

Infrastructure
Keep policies in check

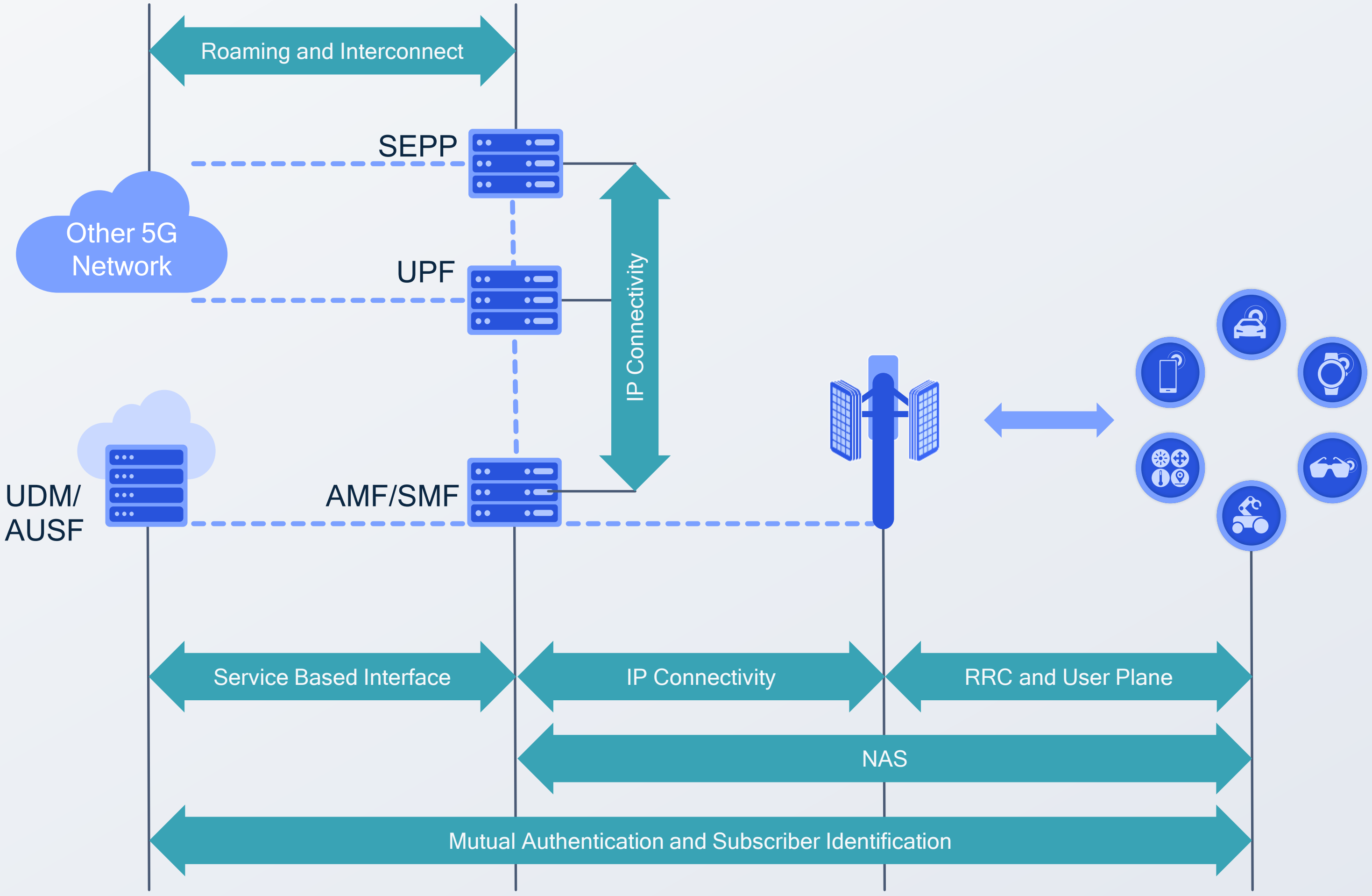
Data
Data integrity and privacy

5G security provides compatibility with zero-trust principles

Zero-trust principles		5G Security
All data sources and computing services are considered resources	→	The 5G network (i.e., UEs, RAN, transport, core, applications, and services) comprises of assets and data sources
All communication is secured regardless of network location	→	Secure communications in 5G include TLS, IPSec, SUCI, and user plane integrity protection
Access to individual [operator] resources is granted on a per-session basis	→	Authentication and key agreements using 5G-AKA, EAP-AKA’, or EAP-TLS. Network slice specific authentication and authorization, secondary A&A for data network access, fine-grained authorization using OAuth in the service-based architecture
Access to resources is determined by dynamic policy	→	The PCF[1] feeds the AMF[2] with access and mobility policies that affect UE authorization to access 5G network resources. The NRF[3] grant access tokens to network functions for service access
Operator monitors and measures the integrity and security posture of all owned and associated assets	→	NWDAF[4] incorporates standard interfaces from the service-based architecture to collect data and evaluate systems in terms of compliance with security policy rules
All resource authentication and authorization are dynamic and strictly enforced before access is allowed	→	OAuth 2.0 token-based authorization for any network function that wants to communicate with another one
Operator collects information about the current state of assets, network infrastructure and communications and uses it to improve its security posture	→	Leverage continuous diagnostic and mitigation (CDM) systems as defined by NIST, and have a GSMA NESAS compliant supply chain risk management (SCRM)

1 Policy Control Function; 2 Access & Mobility Management Function; 3 Network Repository Function; 4 Network Data Analytics Function

5G provides a zero-trust architecture to secure connectivity at scale



End-to-End Security Considerations

Mutual Authentication between device and network

Encryption and Integrity Checking

- Signaling: NAS and RRC
- User plane

Protecting the Subscriber Identity:

- SUCI: IMSI encryption

Protecting the 5G SBA

HTTP/TLS: mutual authentication and data encryption

OAuth 2.0: client authorization by service provider

Securing AN to CN Communication:

IPSec

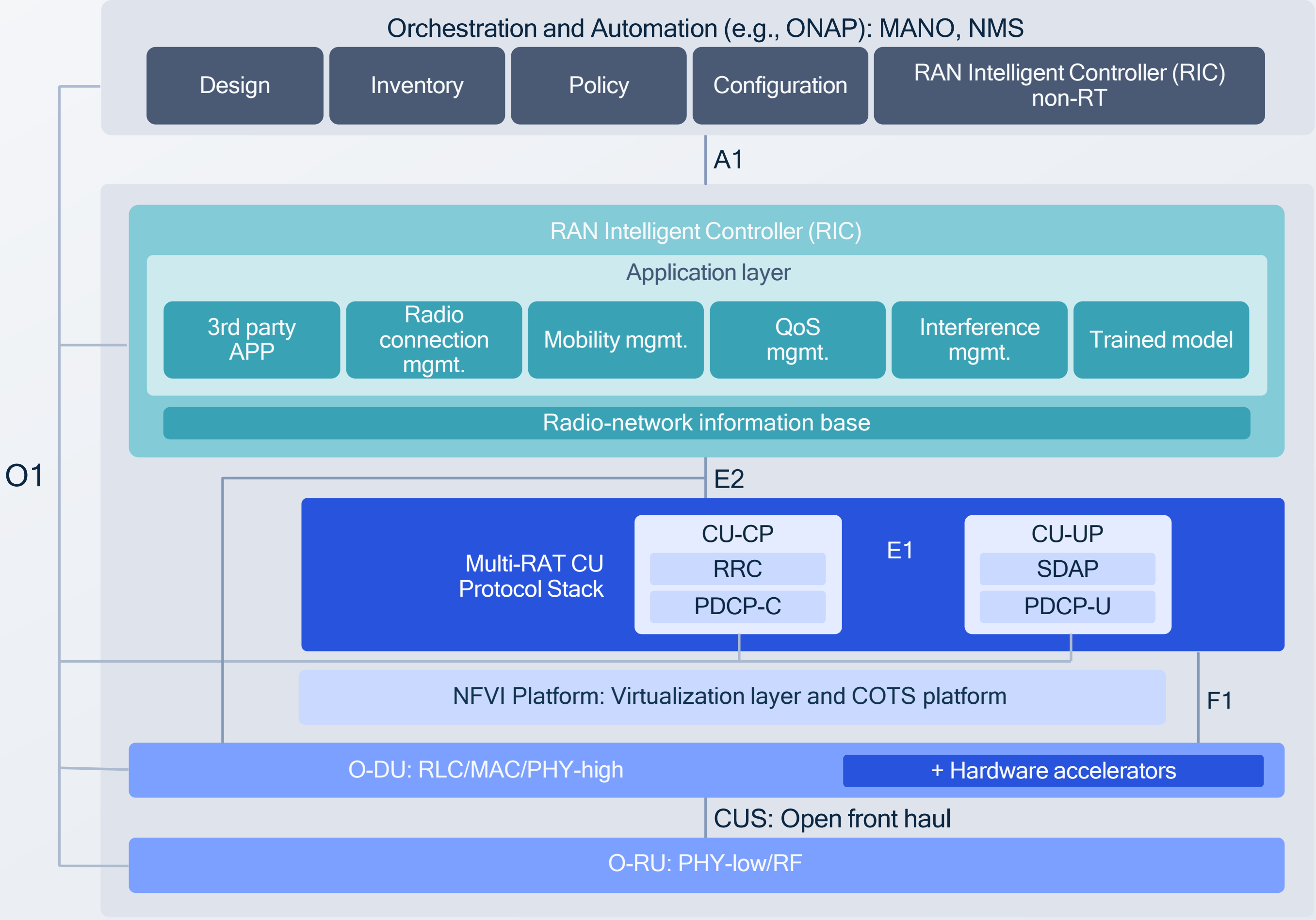
Roaming Security

Security Edge Protection Proxy

PRINS: signaling security

IPUPS: user plane security

Transparency and openness of O-RAN pave the way to a more secure cellular system



O-RAN's disaggregated architecture brings many security benefits such as agility, adaptability, and resiliency

Interface Security

Standards-defined security mechanisms on all interfaces

Software Security

Self-certification encompassing code testing, verification, and signing

Software Bill of Material (SBOM) to secure SW supply chain and lifecycle management

Zero-Trust Model

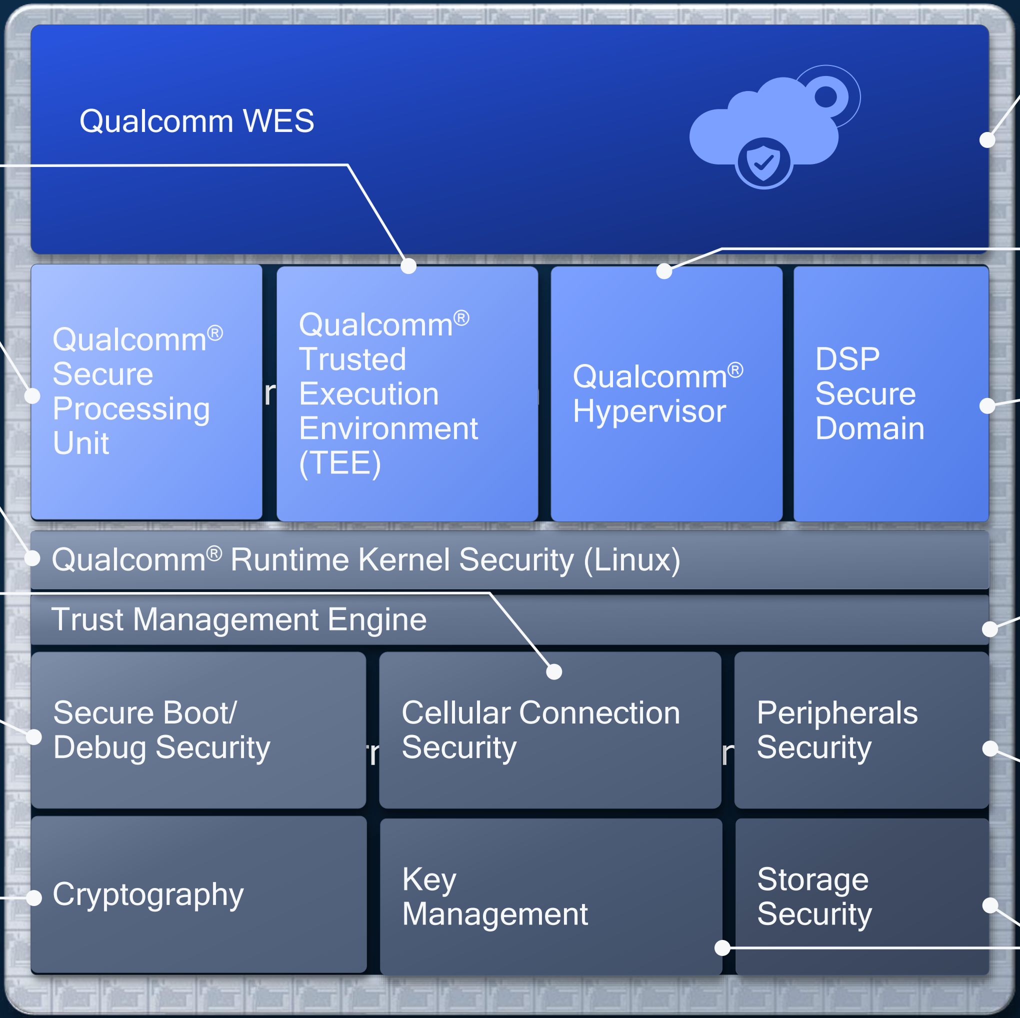
Endpoints are authenticated, authorized, and continuously validated to be granted or keep access to resources

Learn more:

Qualcomm Technologies has a robust chipset security portfolio

Snapdragon® Security Foundations

Enabling a system-wide approach to security with SoC-based HW and SW, and trust-enabling services



Qualcomm WES
Qualcomm® Secure Processing Unit
Qualcomm® Trusted Execution Environment (TEE)
Qualcomm® Hypervisor
DSP Secure Domain
Qualcomm® Runtime Kernel Security (Linux)
Trust Management Engine
Secure Boot/ Debug Security
Cellular Connection Security
Peripherals Security
Cryptography
Key Management
Storage Security

Qualcomm TEE

Qualcomm® Trusted Execution Environment

Qualcomm® Secure Processing Unit

Integrated security with active and passive protections against SCA, FA and invasive attacks

Runtime Kernel Security

Linux Kernel monitoring and protection

Cellular Connection Security

Detecting and protecting against cellular attacks

Secure Boot

Enabling trust in the device initial state (code, configuration)

Debug Security

Policy based debug access control throughout device lifecycle

Cryptography

FIPS certified HW crypto engines enable security without sacrificing performance

Qualcomm® wireless edge services (WES)

Set of services allowing usage of SoC unique hardware credentials to establish and maintain trust in the device

Qualcomm® Hypervisor

Type-1 Hypervisor enabling multiple OS environments to run concurrently and in isolation

DSP Secure Domain

- Performant secure processing
- Qualcomm TEE integration for facial authentication

Trust Management Engine

SoC Root of Trust, providing platform security services

Peripherals Security

Peripherals protection from unauthorized software access

Storage security & Key Management

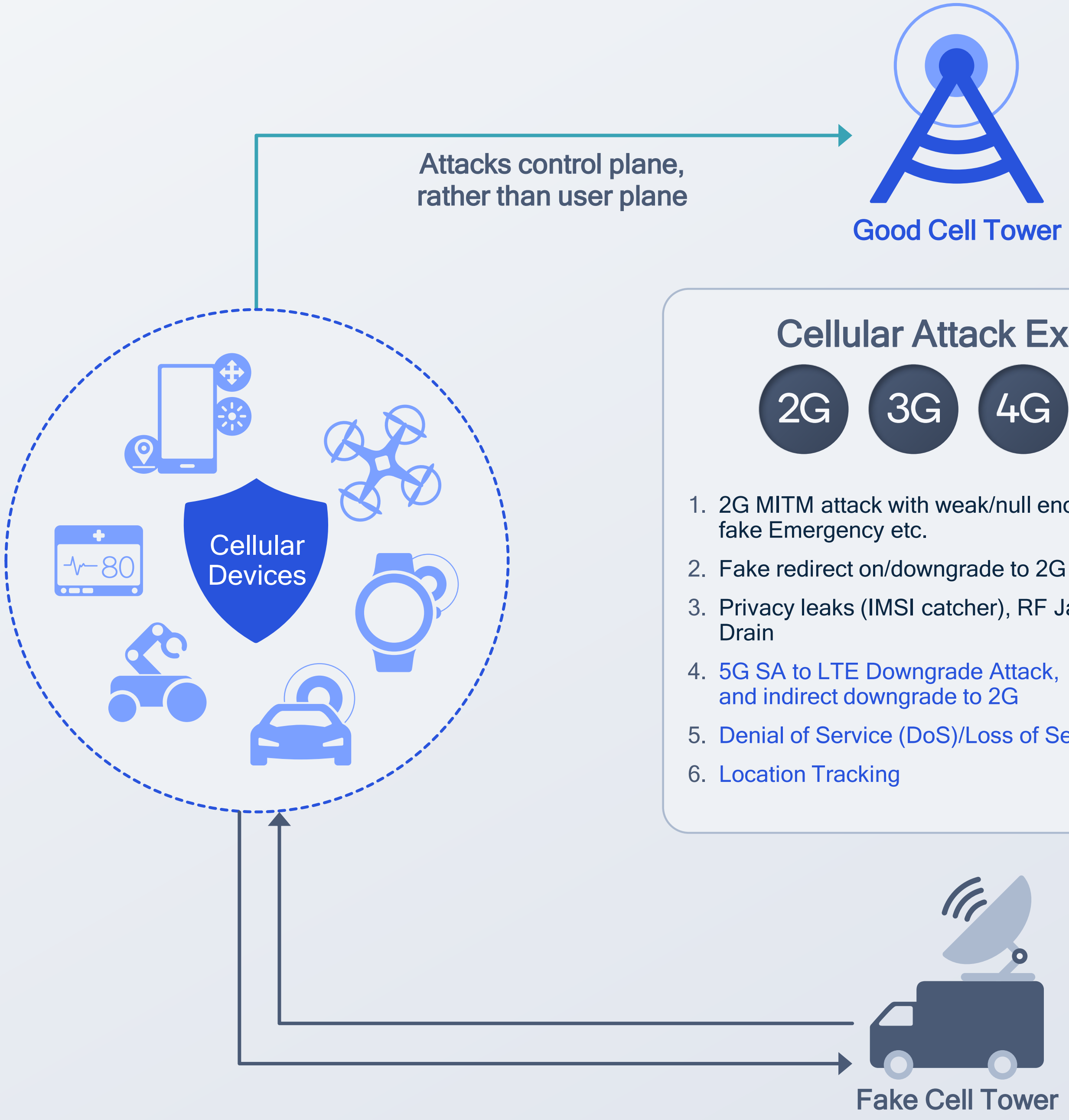
Protection of assets at-rest and in-transit

Qualcomm wireless edge services are offered by Qualcomm Technologies Inc. and/or its subsidiaries.

Cellular Attack Landscape

In China an attacker with a $500 fake base station, small enough to carry in a car, can earn up to $1400 a day.

5.7B spam/fraud messages from fake base stations since 2015



Cellular Attack Examples:

2G 3G 4G 5G

1. 2G MITM attack with weak/null encryption, fake SMS, fake Emergency etc.
2. Fake redirect on/downgrade to 2G
3. Privacy leaks (IMSI catcher), RF Jamming, Battery Drain
4. 5G SA to LTE Downgrade Attack, and indirect downgrade to 2G
5. Denial of Service (DoS)/Loss of Service
6. Location Tracking

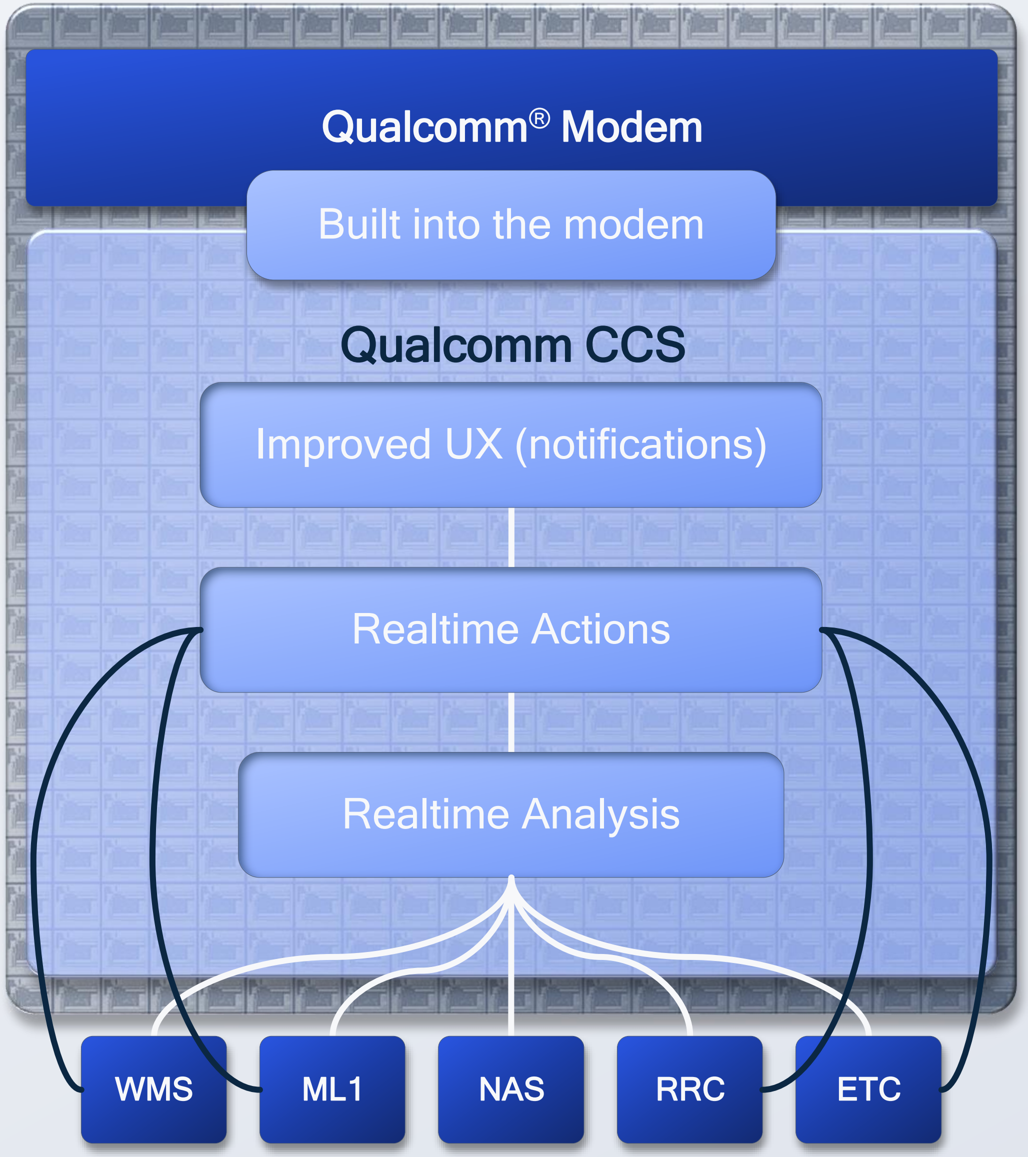
Qualcomm® Cellular Connection Security (CCS) Solution

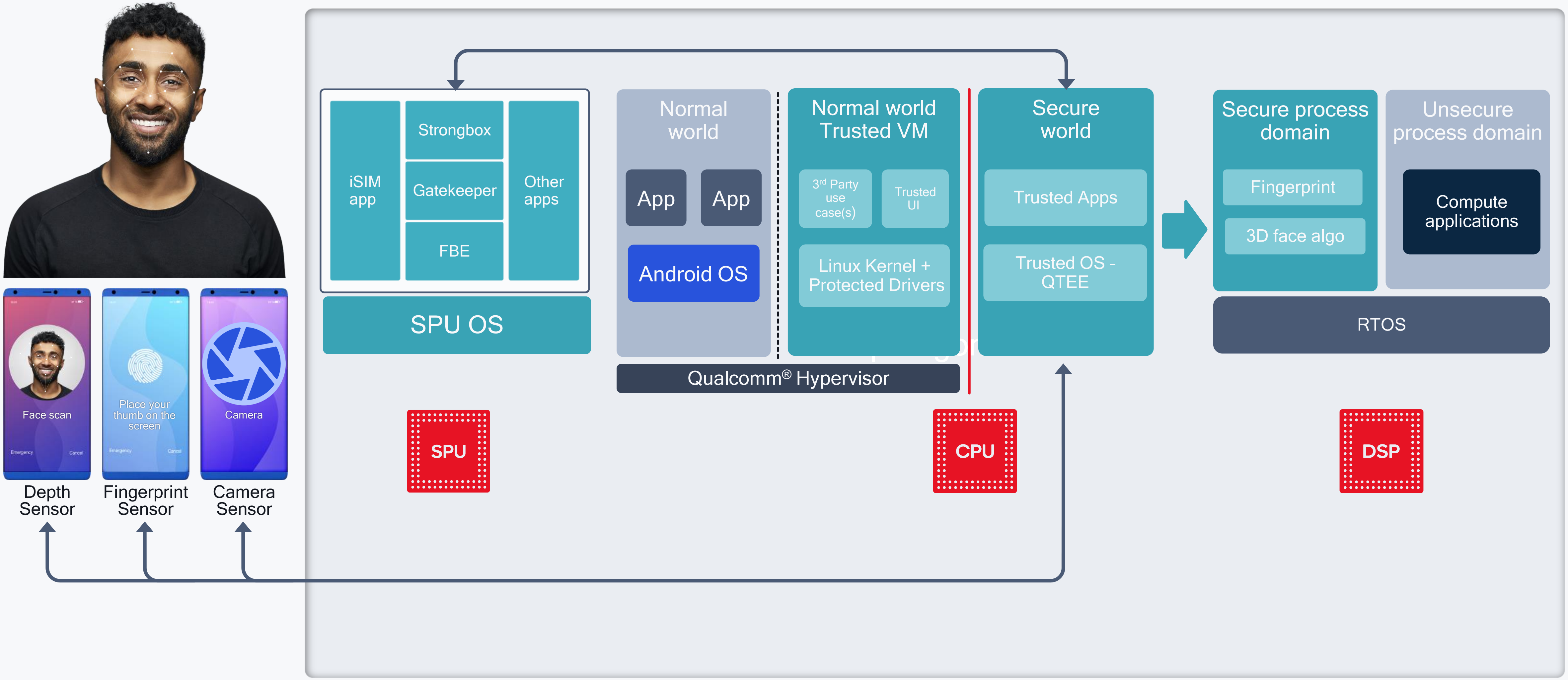
Augments 3GPP Protocol Security

Detection and protection against fake cellular base stations attempting to trick a smartphone into joining the malicious cellular networks, thus protecting device and user data.

Scoring-based threat detection and countermeasures designed within Qualcomm Modem

Radio Access Technologies Supported: 2G, 3G, 4G, 5G





Qualcomm Trusted Execution Environments

Integrated SIM is ready for prime time

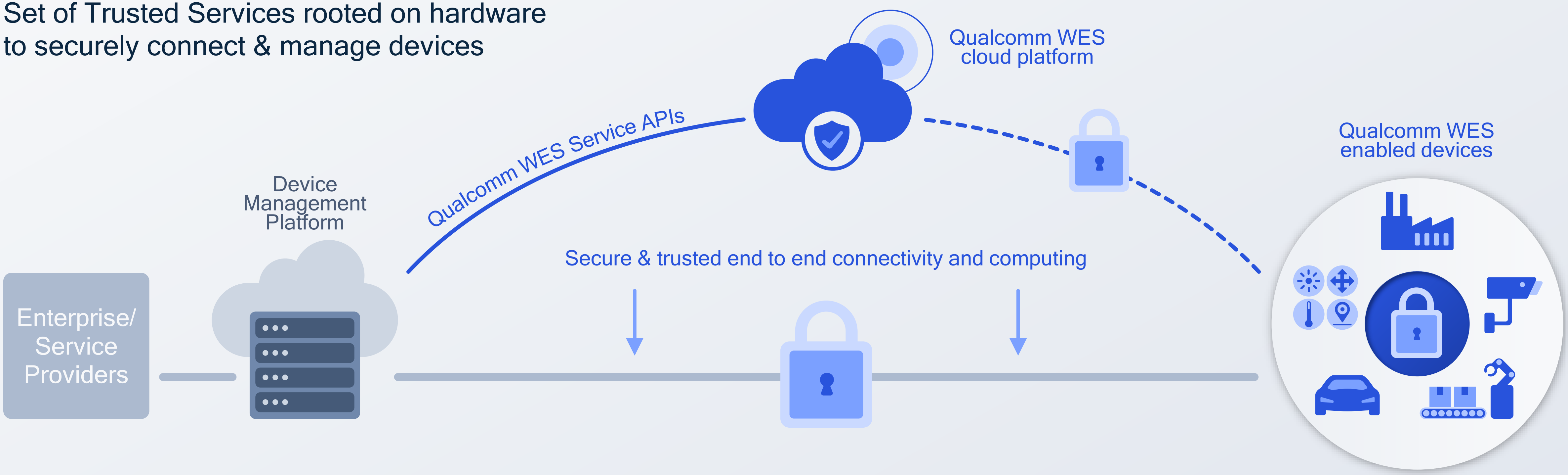
GSMA ieUICC Requirements	Qualcomm	ieUICC/ EUM Partners
SAS-UP ieUICC hardware production security	✓ Accredited supplier	✓ Accredited supplier
SAS-SM ieUICC operational security	✓ Not applicable to Qualcomm Covered by eUICC partner	✓ Accredited supplier
SGP.21 and SGP.25 Hardware and software security	✓ SPU EAL4+ AVA_VAN.5 BSI-CC-PP-0084-2014 certified and in compliance to **SGP.21 Annex J**	✓ Composite certification in accordance with PP.0100 / **SGP.25 and** approved assurance schemes (eSA)
SGP.23 Functional and interoperable ieUICC solution	✓ Not applicable to Qualcomm Covered by ieUICC partner	✓ Certified

✓ GSMA compliant (SGP.24) solution ready for commercial launches

ieUICC Ready For Commercial Launch

Qualcomm WES

Set of Trusted Services rooted on hardware to securely connect & manage devices


Qualcomm WES cloud platform
Qualcomm WES Service APIs
Qualcomm WES enabled devices
Device Management Platform
Secure & trusted end to end connectivity and computing
Enterprise/ Service Providers

Trusted Device Attestation

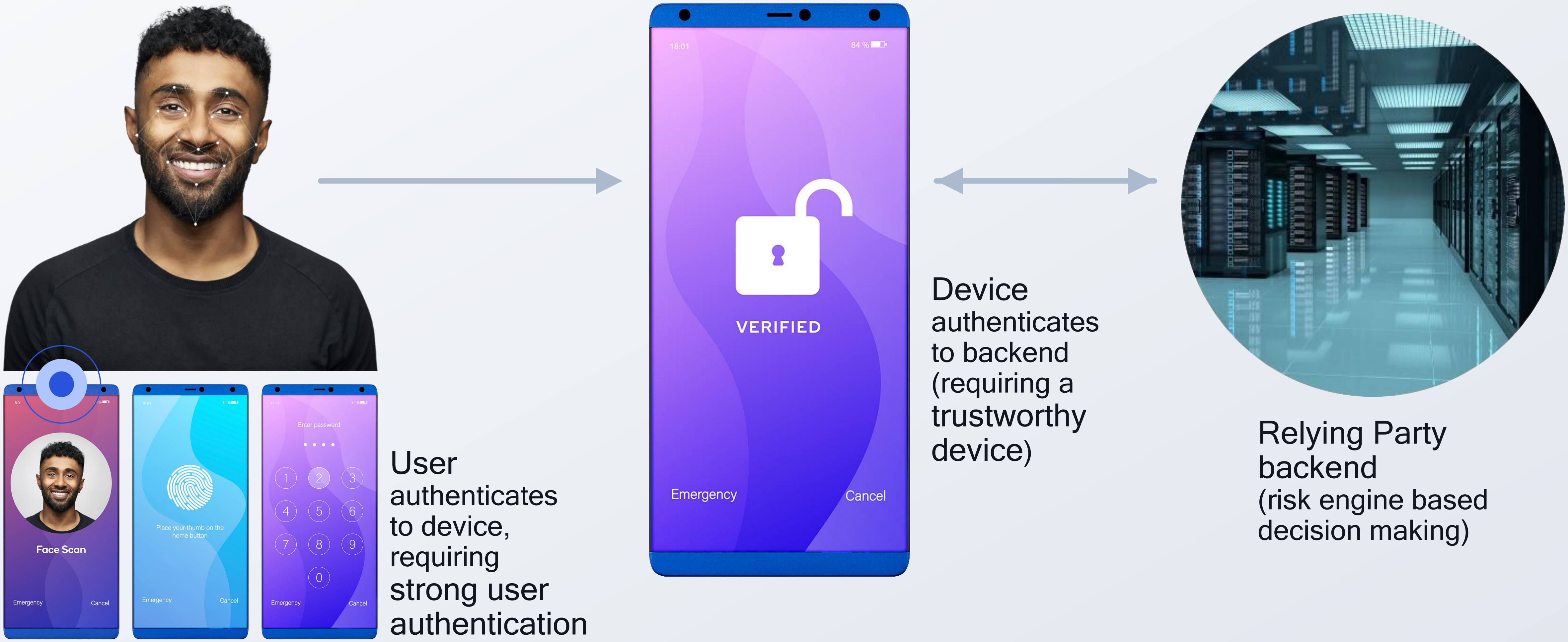
On-demand attestation service for tamper-proof chipset-based identity, device authenticity and connection integrity

Zero Touch Device Provisioning

Plug-n-play onboarding, OTA provision unique device credentials enabling secure remote manageability

Chipset Feature Management

On-demand chipset upgrades, remotely activate/de-activate chipset features as needed during the life cycle of the device

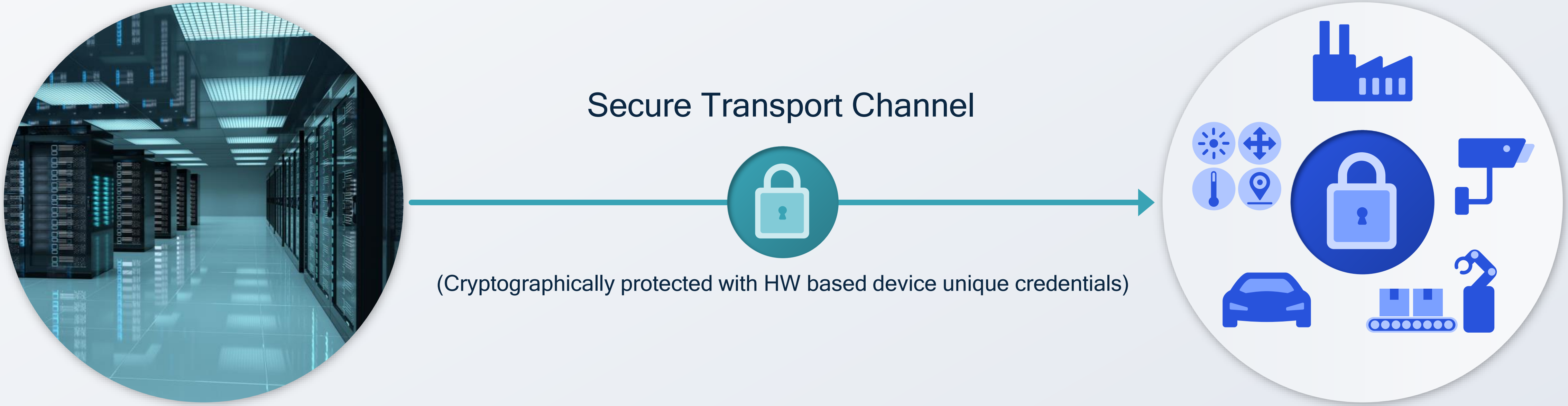


User authenticates to device, requiring strong user authentication

Device authenticates to backend (requiring a trustworthy device)

Relying Party backend
(risk engine based decision making)

Hardware based device authentication service



Secure Transport Channel

(Cryptographically protected with HW based device unique credentials)

Relying Party backend

Qualcomm WES enabled devices

Zero Touch Secure Provisioning Service

Qualcomm WES Value Proposition

Enhanced security

Authenticate device’s identity
Attest device’s software integrity
Establish secure device-cloud communication
Monitor device status & connection integrity

Reduced cost & time-to-market

Seamless, built-in security
No additional hardware BOM required
No need for off-the-shelf security solutions
Logistics of provisioning

Simplified provisioning

Zero-touch provisioning of device credentials
No special provisioning at OEM factory
Secure onboarding based on HW RoT

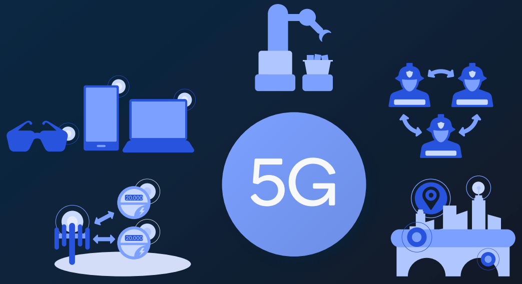
Activate features on-the-fly

Enable pre-built chipset features
Enable preloaded software features

Enabling end-to-end 5G system security at scale

Resilient communication for the connected intelligent edge

Delivering resilient communication requires an end-to-end approach to system security



Zero-trust security is at the core of a resilient system for 5G to deliver a wide range of services

5G already delivers strong security today with focused enhancements coming in 5G Advanced and beyond

Qualcomm

We have a robust chipset security portfolio and are leading the way in realizing new features and services

Thank you

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