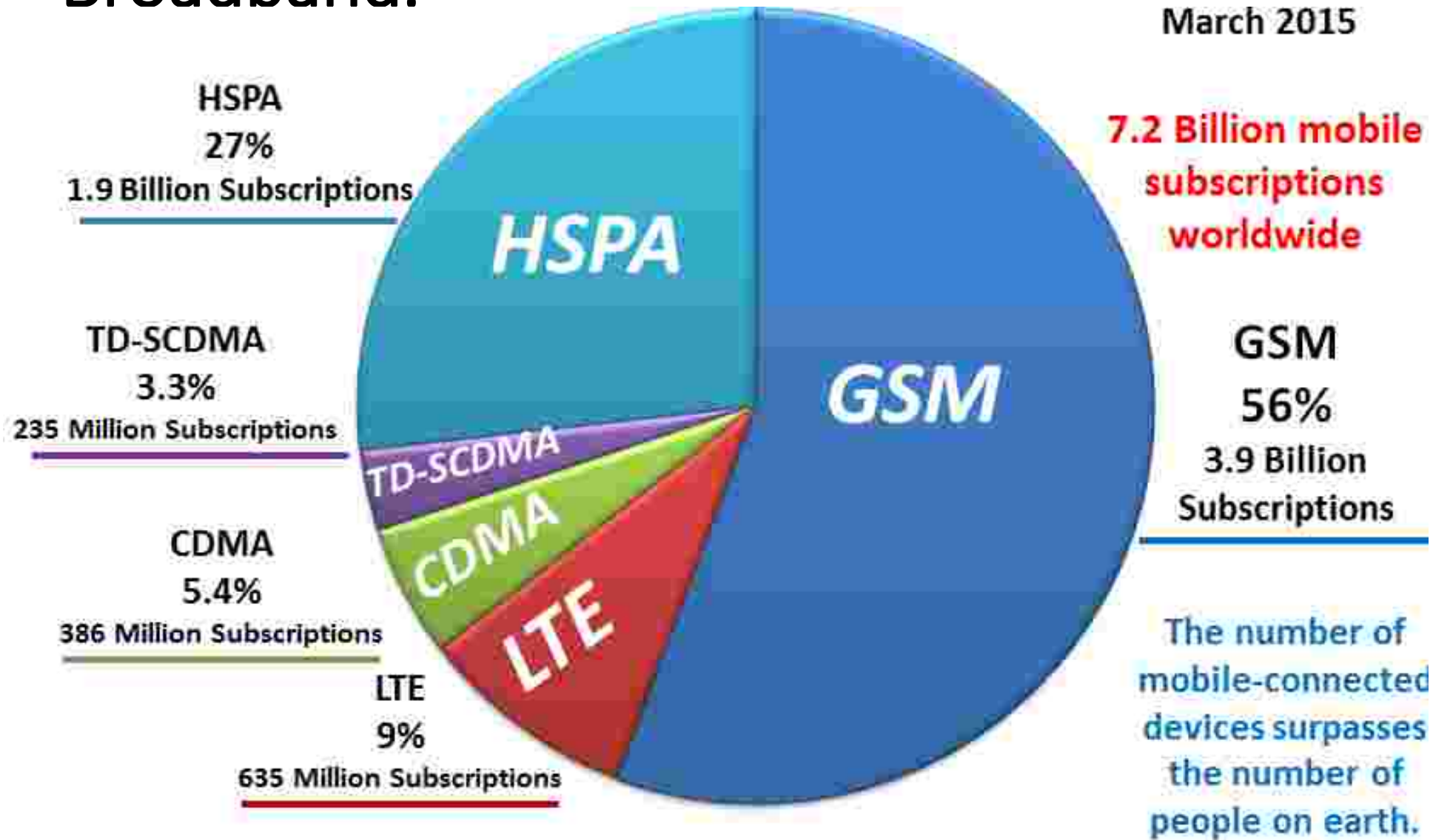


Qualcomm View

www.qualcomm.com/technology

Global Market Share for LTE and HSPA+ Mobile Broadband.



Mobile has made a leap every ~10 years



1G

Analog voice

AMPS, NMT, TACS

1980s



2G

Digital voice

D-AMPS, GSM,
IS-95 (CDMA)

1990s



3G

Mobile broadband

WCDMA/HSPA+,
CDMA2000/EV-DO

2000s



4G

Faster and better MBB

LTE,
LTE Advanced

2010s



Enabling
new services

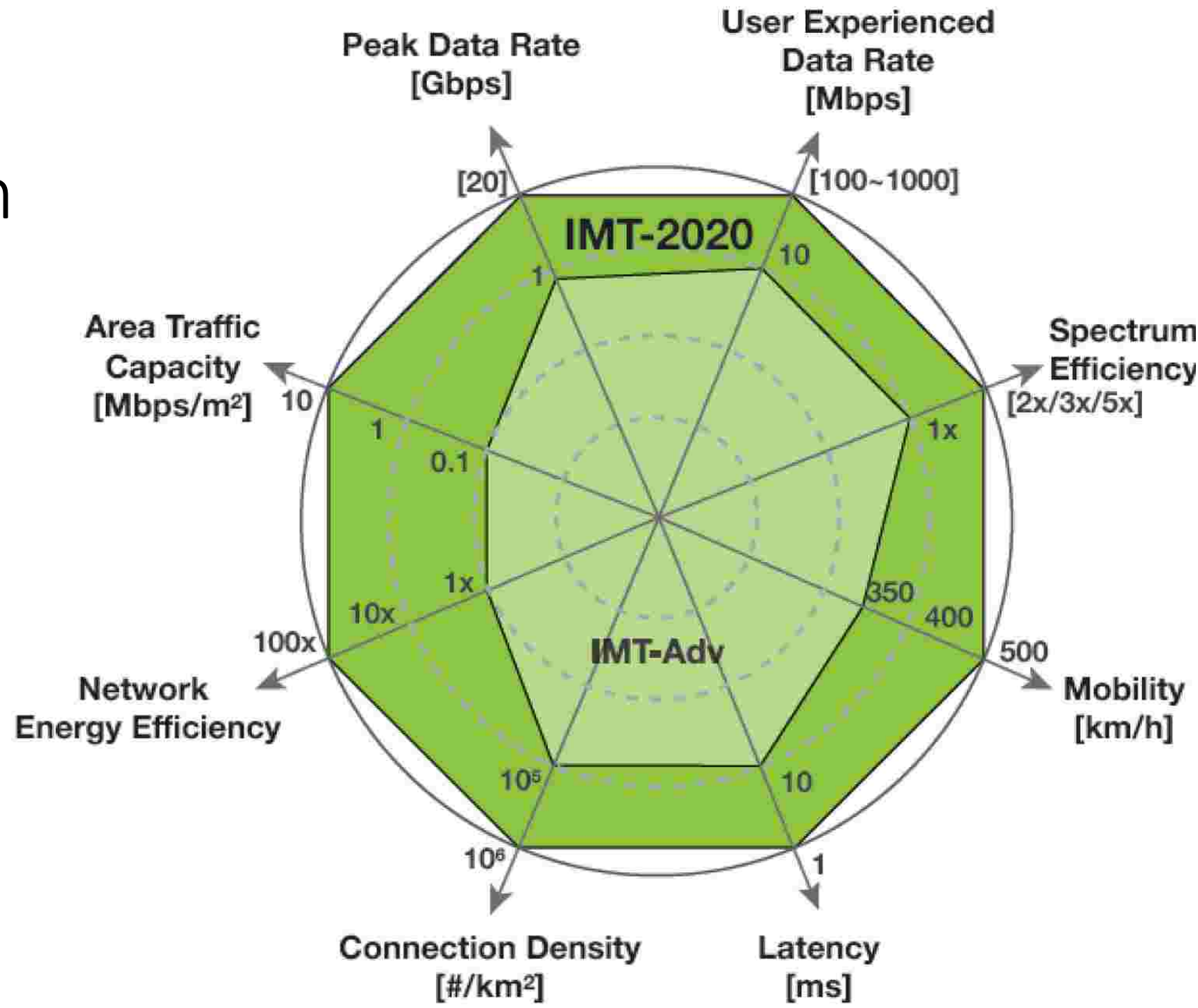
5G

Connecting
new industries and devices

Empowering
new user experiences

IMT-2020

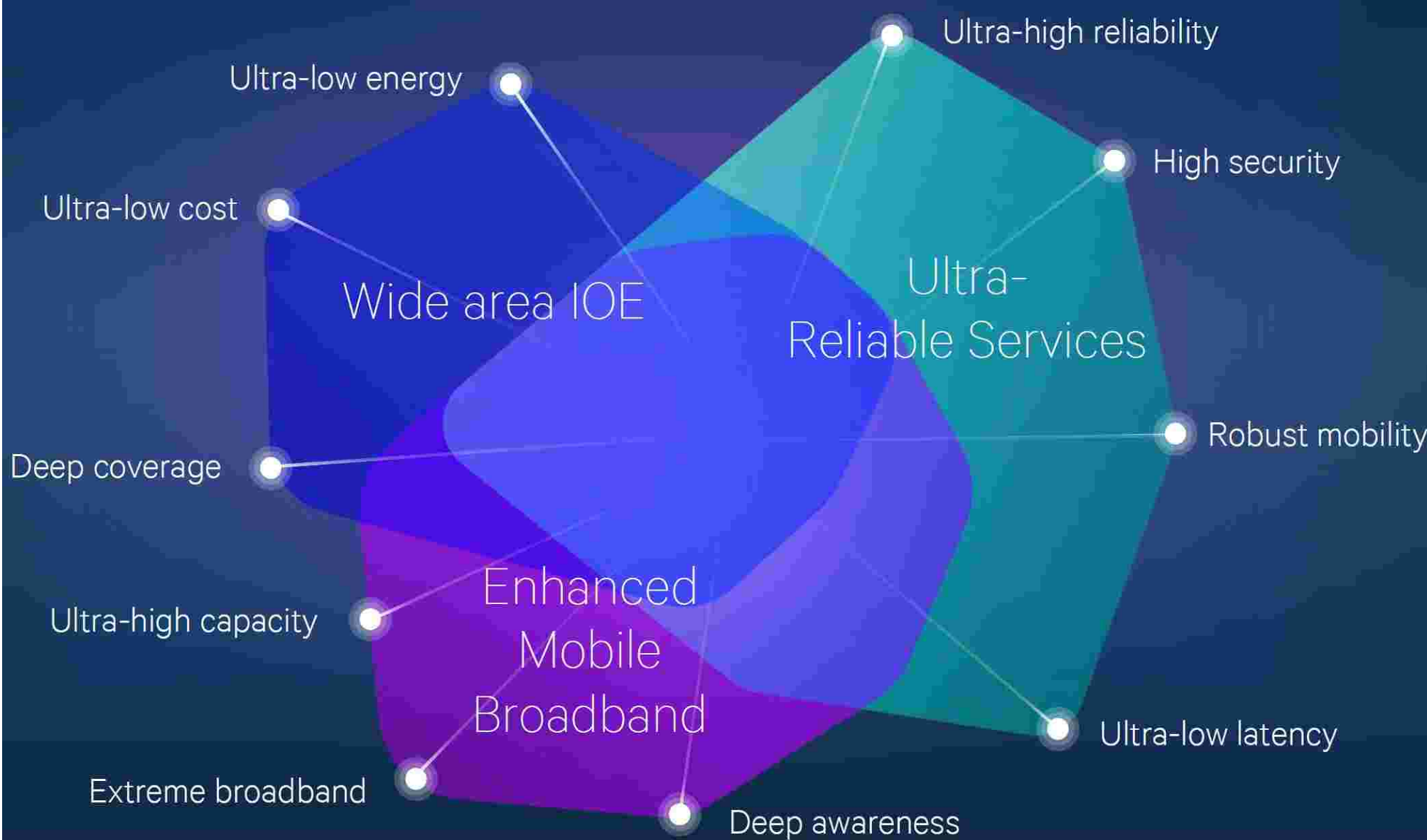
The ITU Vision



5G radio access techniques

- Full self- configuration
- Even denser network deployment
- Context-aware network & devices
- Low latency and high reliability
 - Support licensed & unlicensed spectrum sub-6GHz and above 6GHz including mm Wavebands
 - Integrated access & backhaul
 - Massive spatial processing
 - Coordinated spatial techniques
 - Multiple access for more active connections
 - Device-to-device communication & discovery
 - Multi-hop

Extreme variation of requirements



Key Enhancements to LTE

Release 13

Continual Enhancements

Release 8

FDD and TDD
Flexible bandwidth
1.4 MHz to 20 MHz
DL SU-MIMO (up to 4 layers)
and SDMA
UL Transmit diversity and
SDMA
Downlink peak ~ 300 Mbps
Uplink peak ~ 75 Mbps

Release 9

eMBMS
Dual stream
beamforming
Positioning

Release 10

Carrier Aggregation for up
to 5 cells
Up to 8 DL layers
Up to 4 UL layers
eICIC

Relays
MDT
Downlink peak
~ 3000 Mbps
Uplink peak
~ 1500 Mbps

Release 11

DL and UP CoMP
In-device coexistence
Enhanced eICIC
CA enhancements (for
inter-band support)
ePDCCH
Enhanced beamforming
support
UTDOA

Release 12

D2D discovery and
communication (ProSe)
FDD/TDD aggregation
3GPP/WLAN radio-level
interworking
Small cell discovery and
support of small cell
on/off mechanisms
256QAM support in
downlink
Dual connectivity
Support of interference
suppression on the data
channel
CoMP operation w/ non-
ideal backhaul
Low cost LTE for MTC

mmWave enables 5G Extreme Mobile Broadband

Challenges

- Higher path-loss at mmWave frequencies, susceptibility to blockage
- Robust beam search & tracking
- System design with directional transmissions
- Device cost and RF challenges at mmW

Opportunities

- Availability of large bandwidth from 100s of MHz up to 9 GHz
- Extreme data-rates (e.g. up 10 Gbps)
- Dense spatial reuse can enable extreme network capacity
- Beamforming to overcome poorer propagation
- Flexible deployment with integrated backhaul (200m –500m) and access (100m-150m)

Solutions

- Smart beam search & tracking algorithms
- Antenna management & reconstructive beam forming algorithms
- Coordinated scheduling for proximal user interference management
- Phase noise mitigation in RF components for cheaper devices

Mobile data traffic growth

Industry preparing for 1000x

Richer Content more video - forecast in 2020

- **2/3** of mobile traffic are video in 2017
- Movie (High Definition) **5.93 GB**
- Movie (Standard Definition) **2.49 GB**
- Game for Android **1.8 GB**
- Soundtrack **0.14 GB**
- Book **0.00091 GB**

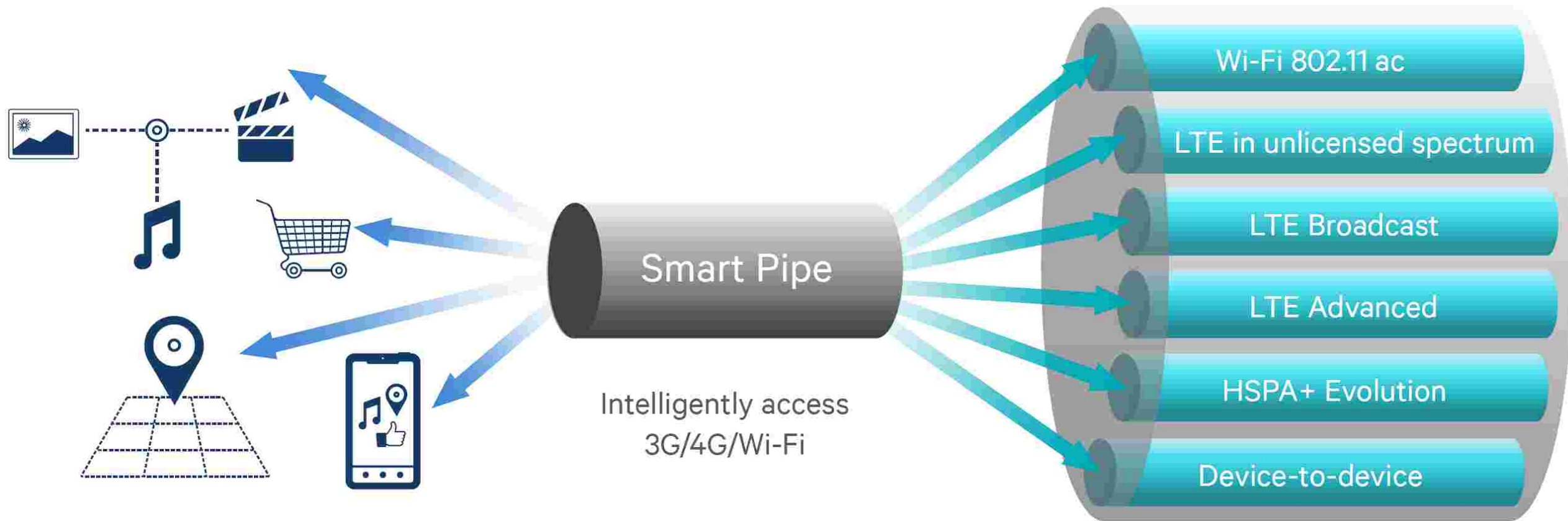
More devices everything connected - forecast in 2020

- **8 ~ Billion** Smartphone
- **25 ~ Billion** Interconnected device

1000x is not just about adding resources

- More spectrum
- More small cells
- Higher efficiency

Squeeze more capacity and value out of spectrum

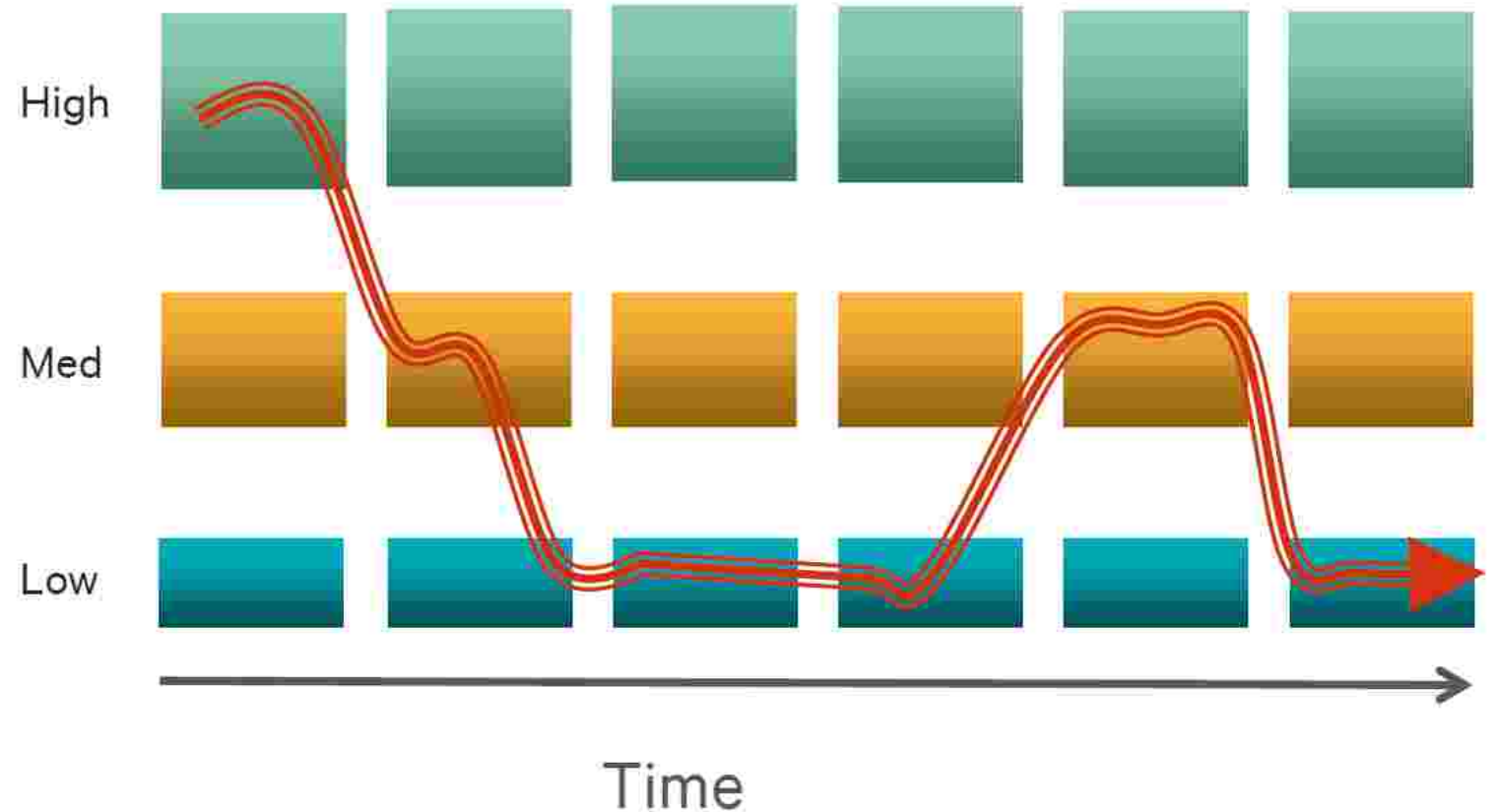


More efficient
apps & services
Compress, cache, adapt, ...

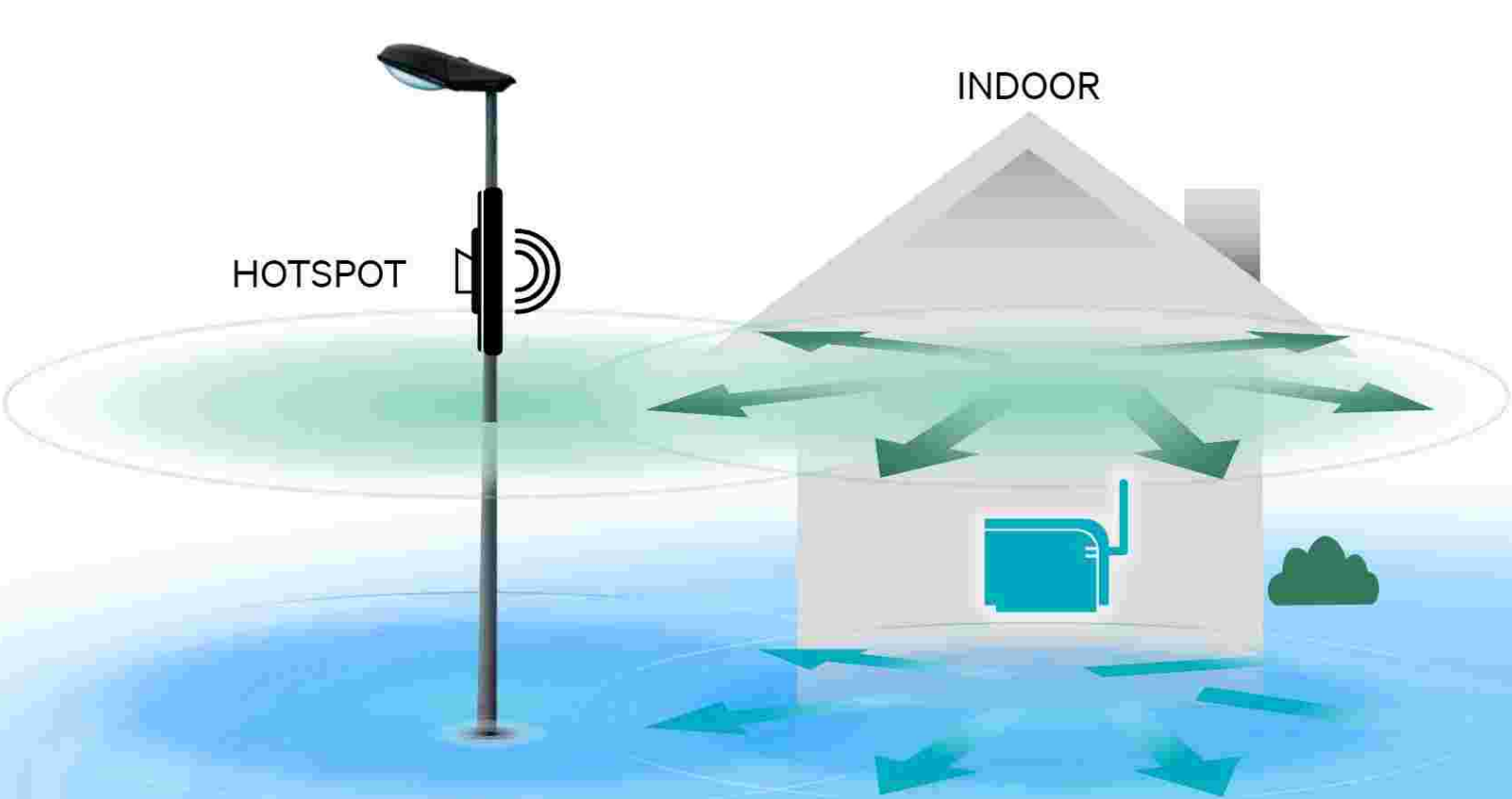
More efficient
data pipe
Evolve 3G/4G/Wi-Fi

Mobile adaptive video streaming

- Enhances mobile user experience—less stalls, higher quality, lower latency
- Device dynamically selects optimal stream, adaptive to changing network conditions



Introduce higher spectrum bands suitable for small cells



3.4 to 3.8 GHz
Emerging as a new small cell band¹

Small cell densification starts in today's bands

Range Expansion

Range
Expansion

Pico



Dual Cell
Device

Reduce Second Carrier
Macro Power

Macro

