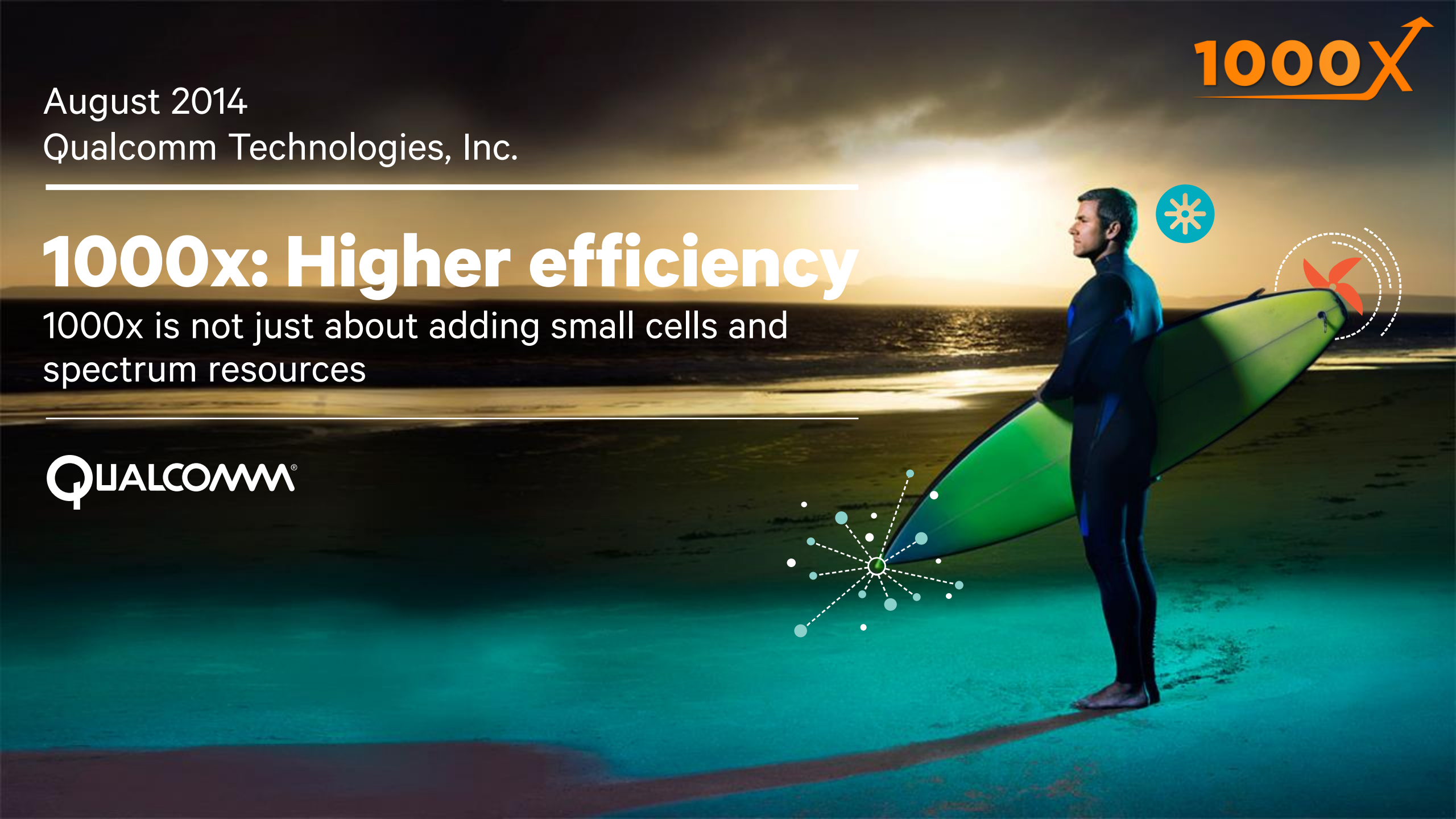
August 2014
Qualcomm Technologies, Inc.

1000x: Higher efficiency

1000x is not just about adding small cells and spectrum resources



Mobile data traffic growth—industry preparing for 1000x

Industry preparing for

1000x

data traffic growth*

Richer Content

more video

~2/3 of mobile traffic will be video by 2017[3]

Bestseller example, richer content:

- **5.93 GB** Movie (High Definition)
- **2.49 GB** Movie (Standard Definition)
- **1.8 GB** Game for Android
- **0.14 GB** Soundtrack
- **0.00091 GB** Book

More devices

everything connected

~25 Billion Interconnected device forecast in 2020[2]

~8 Billion Cumulative smartphone forecast between 2014-2018[1]

[1]Gartner,; Mar'14 [2]Machina Research/GSMA, Dec. '12. [3]Cisco, Feb. '13

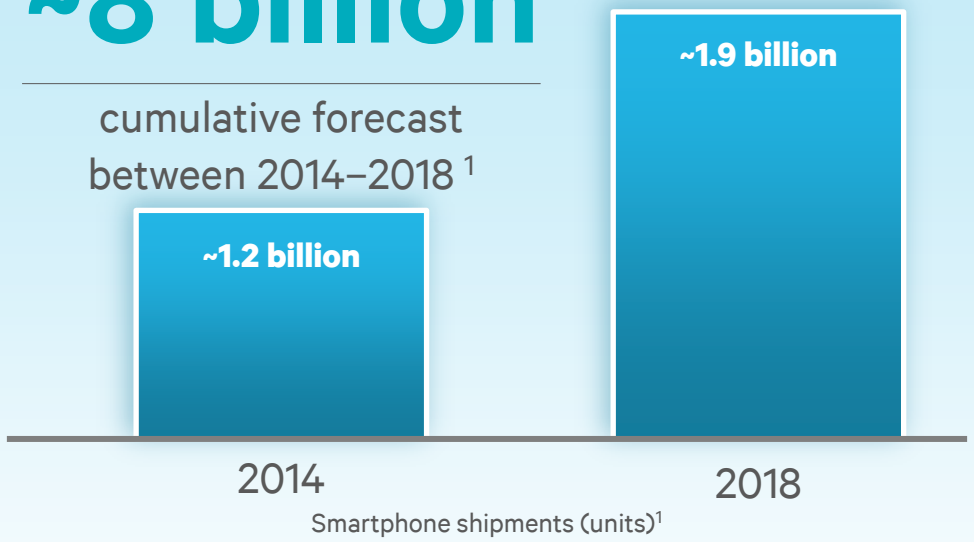
*1000x would be e.g. reached if mobile data traffic doubled ten times, but Qualcomm does not make predictions when 1000x will happen, Qualcomm and its subsidiaries work on the solutions to enable 1000x

Clear trends: accelerated smartphone growth and more video

Smartphone growth

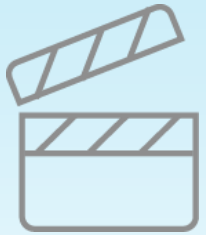
~8 billion

cumulative forecast between 2014–2018 [1]



- Drives more traffic per device
- Need to address 'chatty' application signaling challenges

More mobile video



~2/3

of mobile traffic will be video by 2017[2]

- Drives overall traffic
- Need video optimizations, efficient delivery channels, broadcast solution.

[1]Source: Gartner, March '14; [2]Source Cisco Feb 2013

1000x is not just about adding resources

With **higher efficiency** techniques

The whole is greater than the sum of the parts

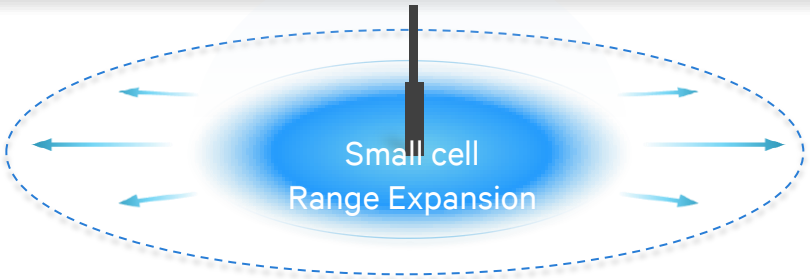
1 + 1 > 2

Squeeze more out of small cells—interference management

- Interference coordination
- Advanced receivers
- Self organizing networks
- Tighter 3G/4G/Wi-Fi interworking

- Opportunistic small cells
- Multiflow across small cells
- And more..

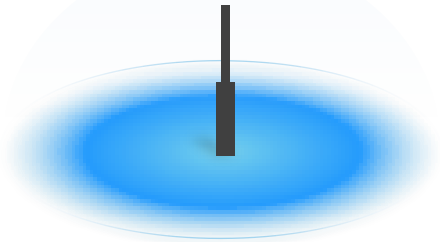
Even better with next generation techniques



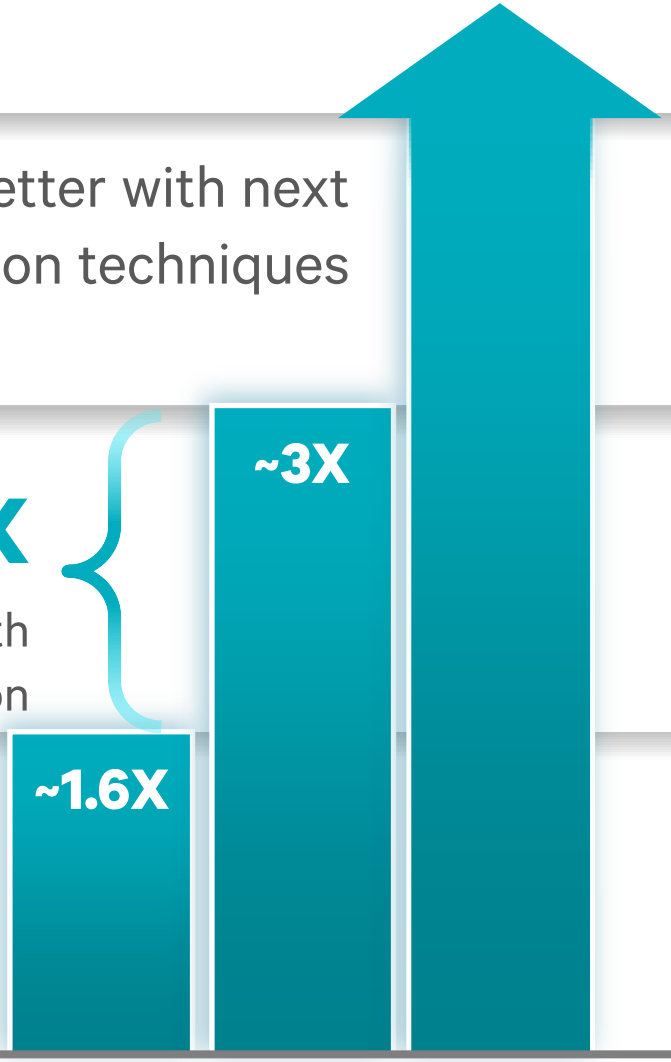
~2x

additional gain with range expansion

Macro + 4x



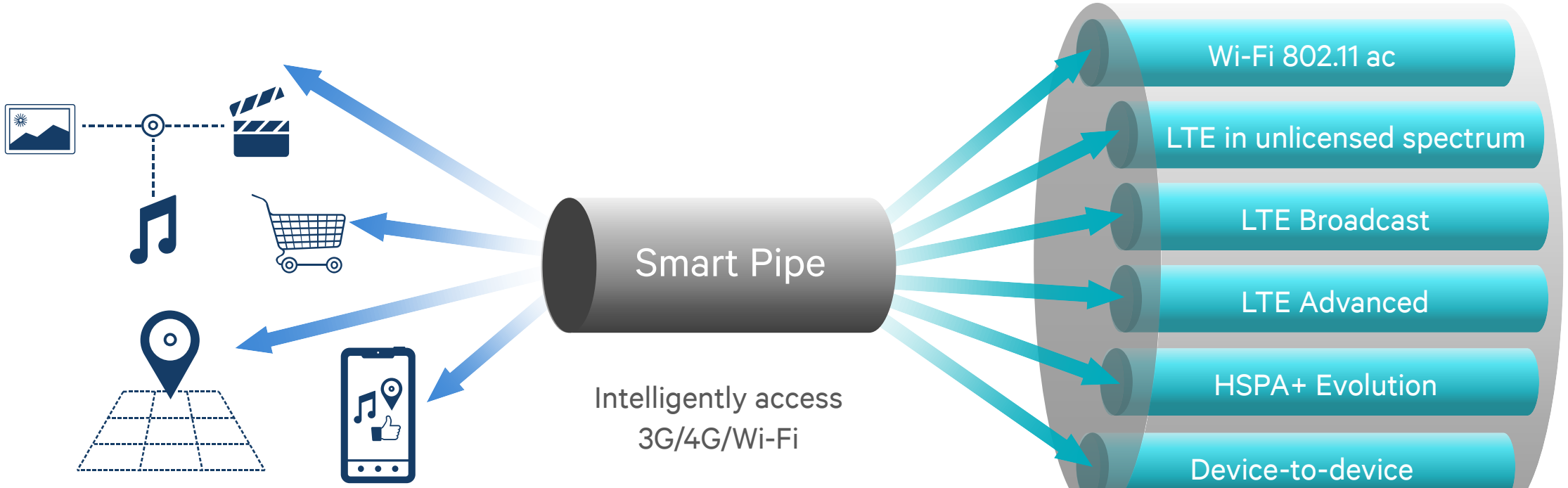
4 small cells added



Median gain versus macro only baseline

HSPA+ example, similar gain for LTE Advanced

Squeeze more capacity and value out of spectrum

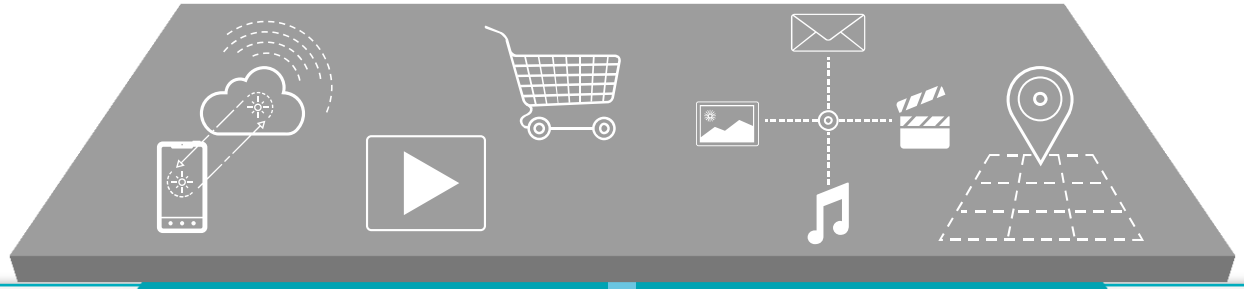


More efficient
apps & services
Compress, cache, adapt, ...

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

1) More efficient apps and services

Optimizations on multiple levels



Dash adapts video to mobile
HEVC/H.265 video uses
~40% less than today's H.264

Improved video/audio codecs

Higher level optimization/compression

Possible today
- Uplink compression
- System optimizations

High level OS

Lower level optimizations
Such as uplink HTTP payload compression (LTE/HSPA+)[1]

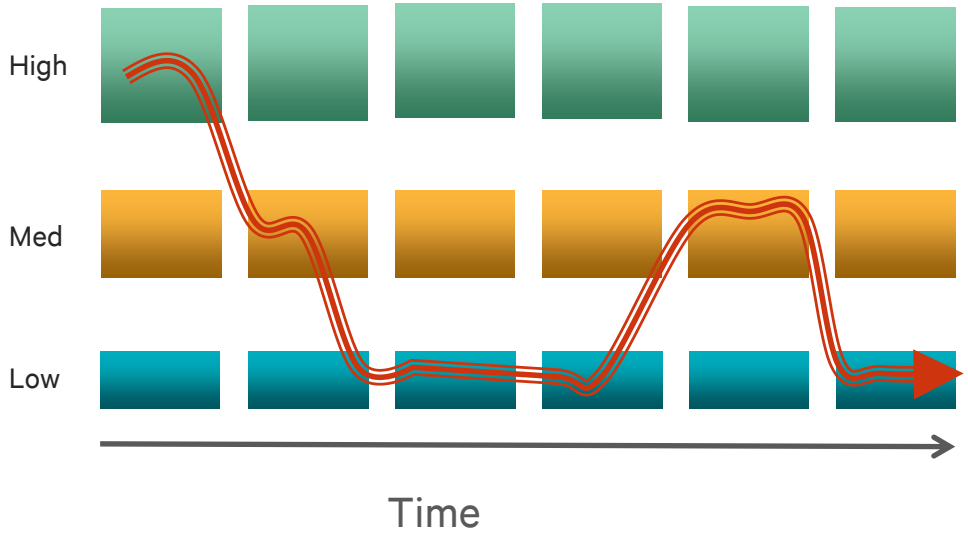
Future: more efficient compression
- 30-40% improved UL throughput
- ~70% reduction in signaling[2]

[1]Such as adding payload (e.g. HTTP GET & POST packets) compression to the PDCP layer, header (RoHC/IPHC) compression already resides in PDCP. Uplink compression is suitable since highly compressible HTTP packets are ~70% of uplink smartphone data volume (based on Qualcomm Technologies' logs). [2]Reduction in Radio Resource Control (RRC) transitions, which drives network signaling, frees up resources for more data capacity

Mobile adaptive video streaming—DASH

Enhances mobile user experience—less stalls, higher quality, lower latency

Video encoded into streams of different quality



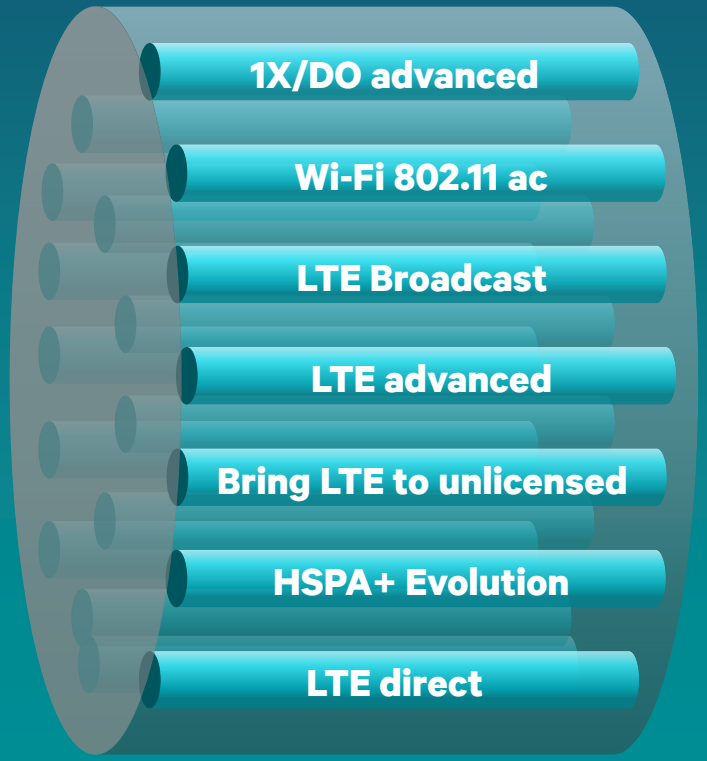
Device dynamically selects optimal stream, adaptive to changing network conditions

Open standard published —commercial in 2012

Global industry support by 50+ companies

Uses existing web delivery infrastructure

2) More efficient data pipe — key examples for 1000x



- Bring LTE benefits to unlicensed spectrum
- Better delivery channel: LTE broadcast
- Smartphone signaling: HSPA+ FE-FACH

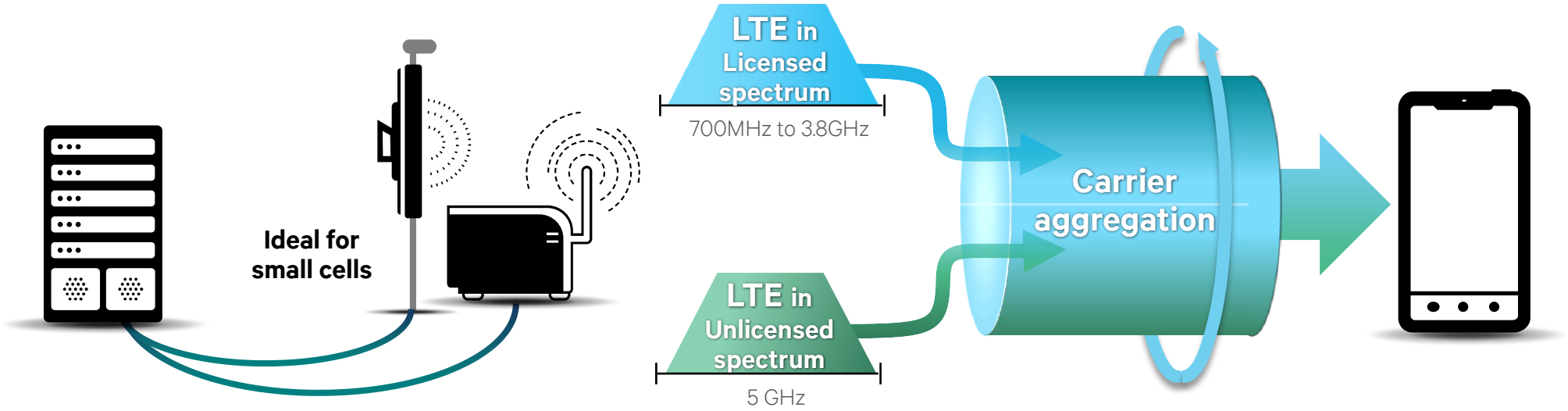
Extending the benefits of LTE Advanced to unlicensed spectrum

Better network performance

Longer range and increased capacity[1]

Enhanced user experience

Thanks to LTE Advanced anchor in licensed spectrum with robust mobility



Unified LTE Network

Common LTE network with common authentication, security and management.

Coexists with Wi-Fi

Features to protect Wi-Fi neighbors

[1] Compared to carrier Wi-Fi

Leverages existing LTE standards, ecosystem and scale

LTE transmitted according to unlicensed spectrum regulations, such as power levels

1 Large scale, global LTE deployments

- 270+ network launches in 100+ countries[1]
- LTE Advanced 3GPP R10 launched June 2013

2 LTE in unlicensed spectrum for USA, Korea and China

- LTE Advanced 3GPP R10/R11/R12
- Targets 5 GHz unlicensed bands
- Wi-Fi and LTE co-existence features[2]

3 LTE in unlicensed spectrum everywhere

- Extend deployment to regions with 'Listen Before Talk' (LBT) regulations
- Optimized waveform enabling LBT, carrier discovery and expanded uplink coverage
- Candidate for 3GPP R13 standard

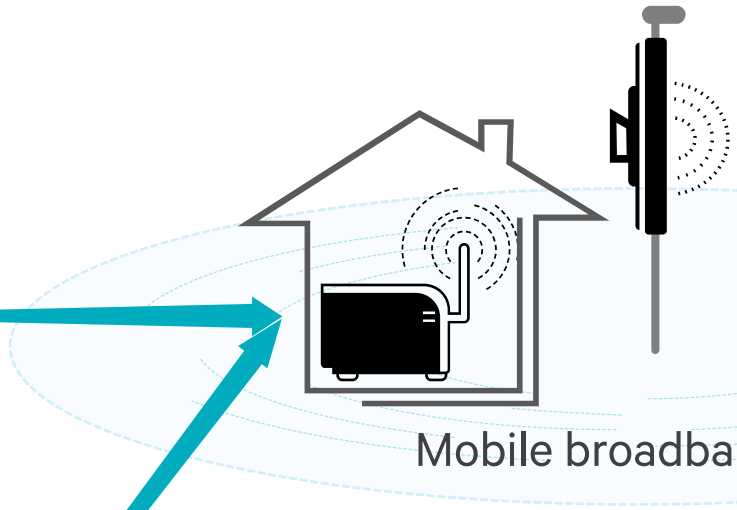
[1]Per GSA as of as of Feb 5th 2014. [2] With Carrier Sensing and Adaptive Transmission (CSAT) in the time domain, in addition to channel selection and opportunistic use of unlicensed spectrum .

A leader in all solutions to best leverage unlicensed spectrum

Committed to continued leadership in both Mobile 3G/4G and Wi-Fi

Licensed Spectrum
Cleared spectrum for 3G/4G, ASA for 3G/4G
Exclusive use

Unlicensed Spectrum
Multiple technologies (Wi-Fi, LTE in unlicensed)
Shared use



LTE Advanced for licensed and unlicensed spectrum

Mobile operator managed service with unified LTE network aggregating licensed and unlicensed spectrum[1]

3G/4G for licensed and carrier Wi-Fi for unlicensed spectrum

Mobile operator managed service with tighter Wi-Fi integration for better offload and enhanced services

Wi-Fi in unlicensed spectrum

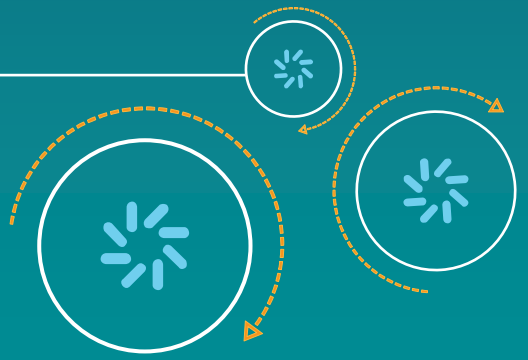
Local area access for private/residential, enterprise users

[1]With Wi-Fi for backward compatibility

LTE broadcast

Addressing many users means huge gains.

But what about just a few users?



LTE broadcast

flexible and
better use of spectrum

5

users per site
consume same content

7x

throughput gain

Source: Qualcomm Research, a division of Qualcomm Technologies, Inc.

LTE broadcast

flexible and
better use of spectrum

2

users per site
consume same content

3x

throughput gain

Source: Qualcomm Research, a division of Qualcomm Technologies, Inc.

LTE broadcast

flexible and
better use of spectrum

1

users per site
consume same content

1.7x

throughput gain

Source: Qualcomm Research, a division of Qualcomm Technologies, Inc.

Dynamically move users to LTE broadcast

Smarter pipe:
detect content, on the fly,
that should use broadcast

Source: Qualcomm Research, a division of Qualcomm Technologies, Inc.

Ever increasing smartphone application traffic

Excessive signaling due to frequent small data bursts in the background[1]

1) Design efficient applications/compress

2) Higher ‘signaling’ pipe capacity

3) Smart pipe—gate background requests

[1]Applications push notifications, updates, messages to users, even when application is not active, could be multiple times per hour. This causes excessive network signaling due to setting up and tearing down the data channel for small, short, but frequent data bursts.

HSPA+ example: 10x improved application ‘signaling’ pipe

Commercial HSPA+

R7/R8 CELL-FACH[1]

HSPA+ advanced

R11 FE-FACH[3]

Small data bursts

Up to 90% reduced signaling load
over HSPA

Another **>10x** capacity over HSPA+

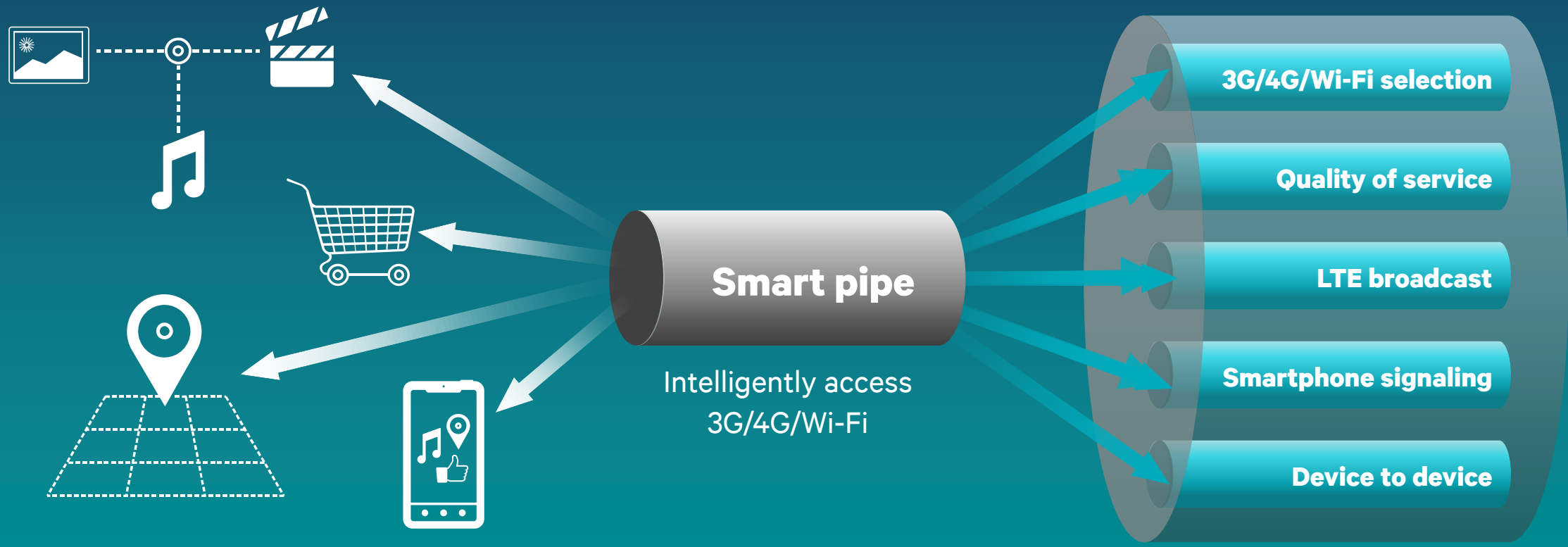
Non full-buffer applications

Extended battery life
over HSPA[2]

Further extended battery life

[1]R7/R8 allows small amounts of data to be efficiently transported in CELL-FACH state: up to 90% reduction in network signaling load due for social media example. [2]Cell-DCH w/ R7 CPC allows non full buffer apps to use connected mode, DCH, more efficiently (DTX/DRX). [3]A main enhancements is downlink triggered feedback (CQI) and acknowledgements on the FACH reverse link, which makes FACH efficient like a regular HSPA link, see simulation assumptions in R1-112679

3) Smart pipe

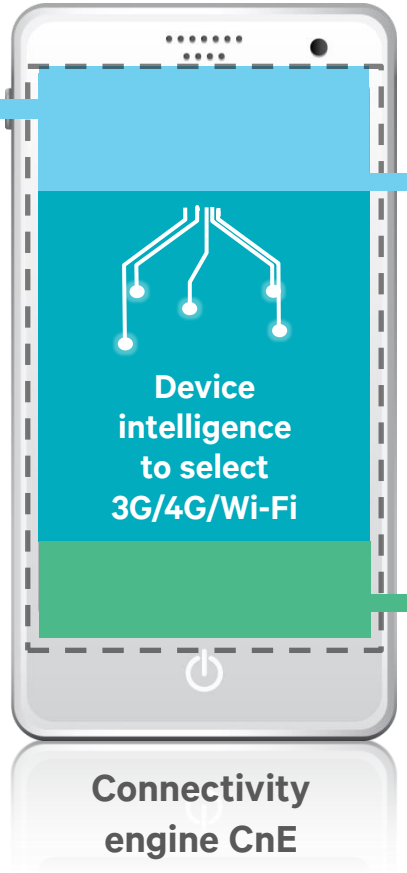

Smart pipe
Intelligently access
3G/4G/Wi-Fi
3G/4G/Wi-Fi selection
Quality of service
LTE broadcast
Smartphone signaling
Device to device

We need both device and standards optimizations

To intelligently access 3G/4G/Wi-Fi

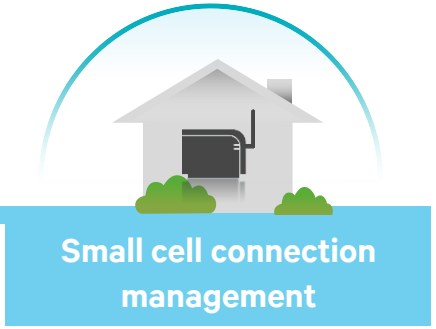
Qualcomm® Technologies unique device optimizations

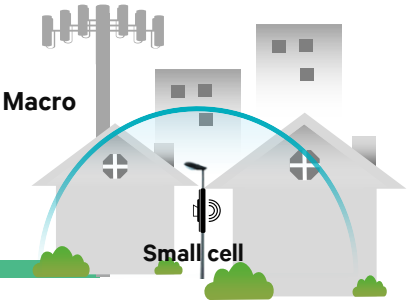
- Select Wi-Fi based on multiple inputs (policy, device, traffic type)
- Real-time Wi-Fi quality estimation
- Background traffic aggregation
- Opportunity for context awareness, e.g. location



Qualcomm® Technologies unique enhancements

- 3G/4G/Wi-Fi selection using both network and device information
- Even better combining Qualcomm Technologies' device CnE and small cell connection management



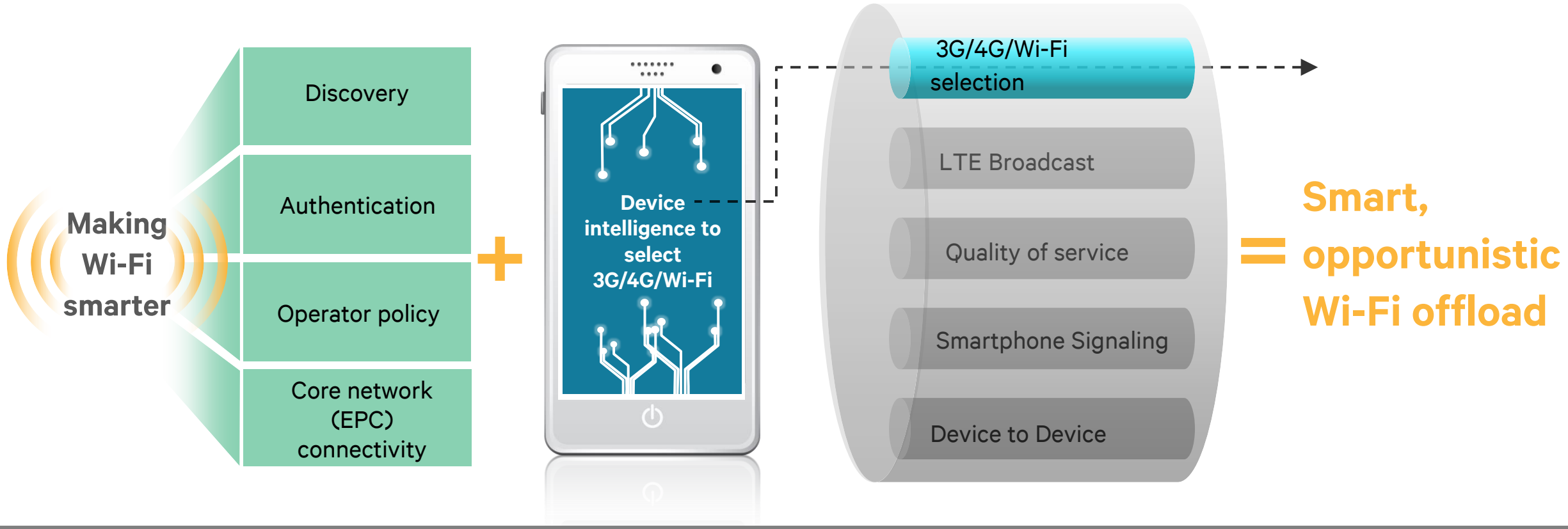


Standards based enhancements[1]

- Seamless Wi-Fi discovery/access
- Authentication and security
- Operator control/policies
- Seamless and selective mobility
- Tighter 3G/4G and Wi-Fi interworking

[1]Seamless Wi-Fi access with Passpoint/Hotspot 2.0 for automatic discovery and connectivity. Wi-Fi Authentication based on 3G/4G EAP-SIM/AKA. Operator policies based on 3GGG ANDSF and OMA-DM (3GPP R8). Seamless mobility using GTP in core network (EPC), and refined ANDSF (3GPP R9/10/11) for selective traffic/flow mobility. Further 3G/4G and Wi-Fi interworking targeted 3GPP R12, such as managing Wi-Fi access through 3G/4G

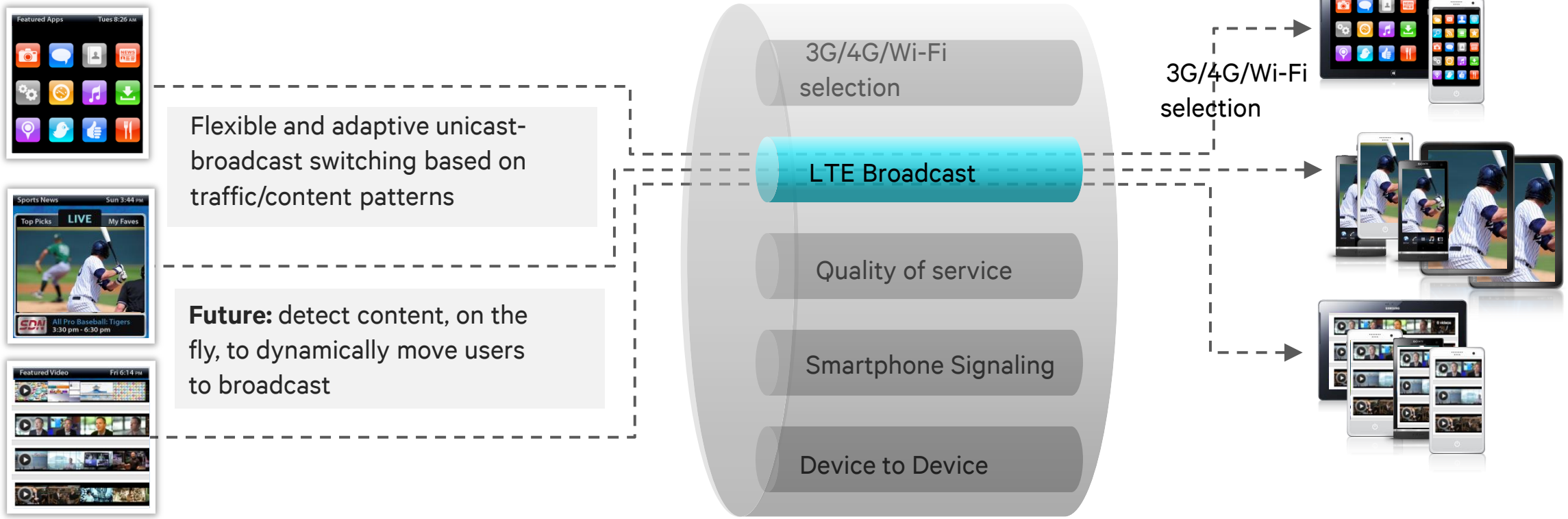
Smart 3G/4G/Wi-Fi selection—carrier Wi-Fi example



Maximize access for higher value core services—offload lower-value traffic[1]

[1]Such as OTT= Over The Top Services or some BE=Best Effort traffic.

Smart LTE broadcast—capacity & revenue opportunity



Live events

- Live sporting events
- Breaking news
- Venuecasting

Manage congestion

- Breaking news triggered content
- Top video clips
- Machine-to-machine

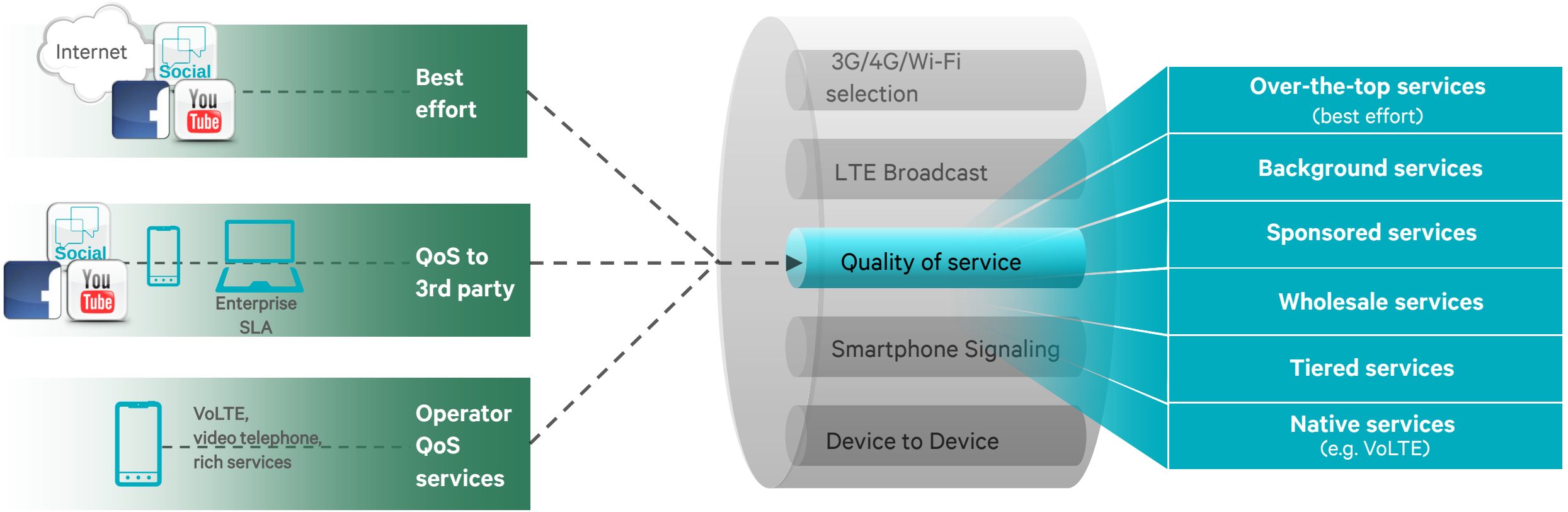
Offload data

- Application updates
- Firmware updates
- Live tickers

Distribute emedia

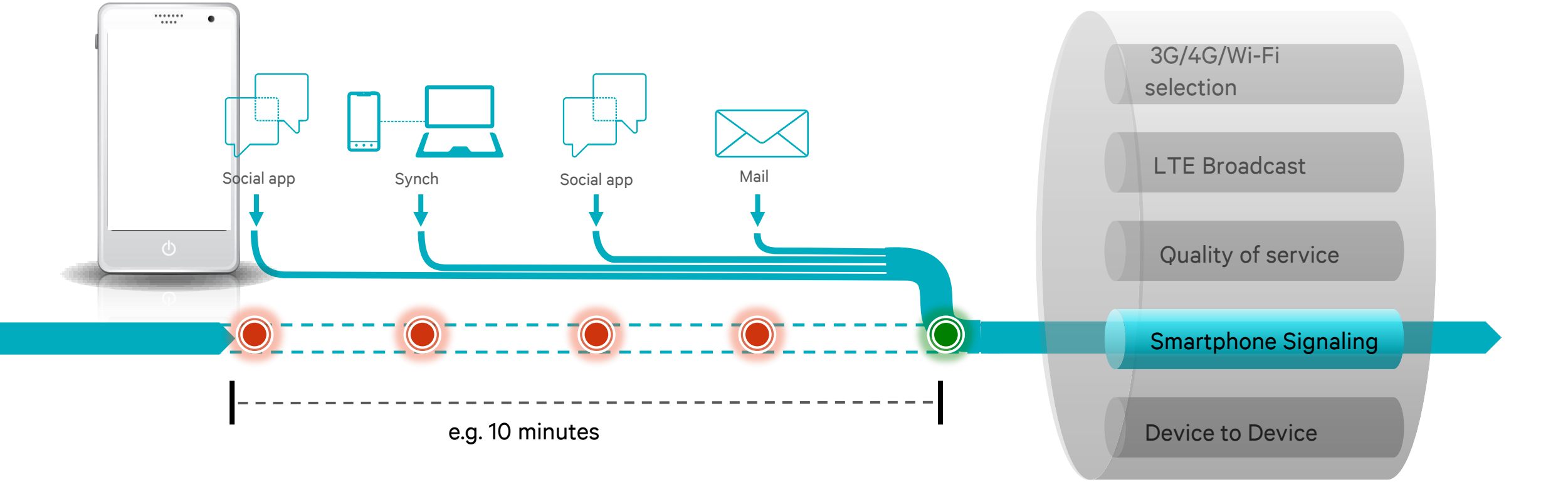
- Print media delivery
- Targeted advertising
- eLearning

Smart pipe—QoS and value-based revenue models



Smart pipe—aggregate traffic by gating application requests

Reducing network signaling by ~30%[1]

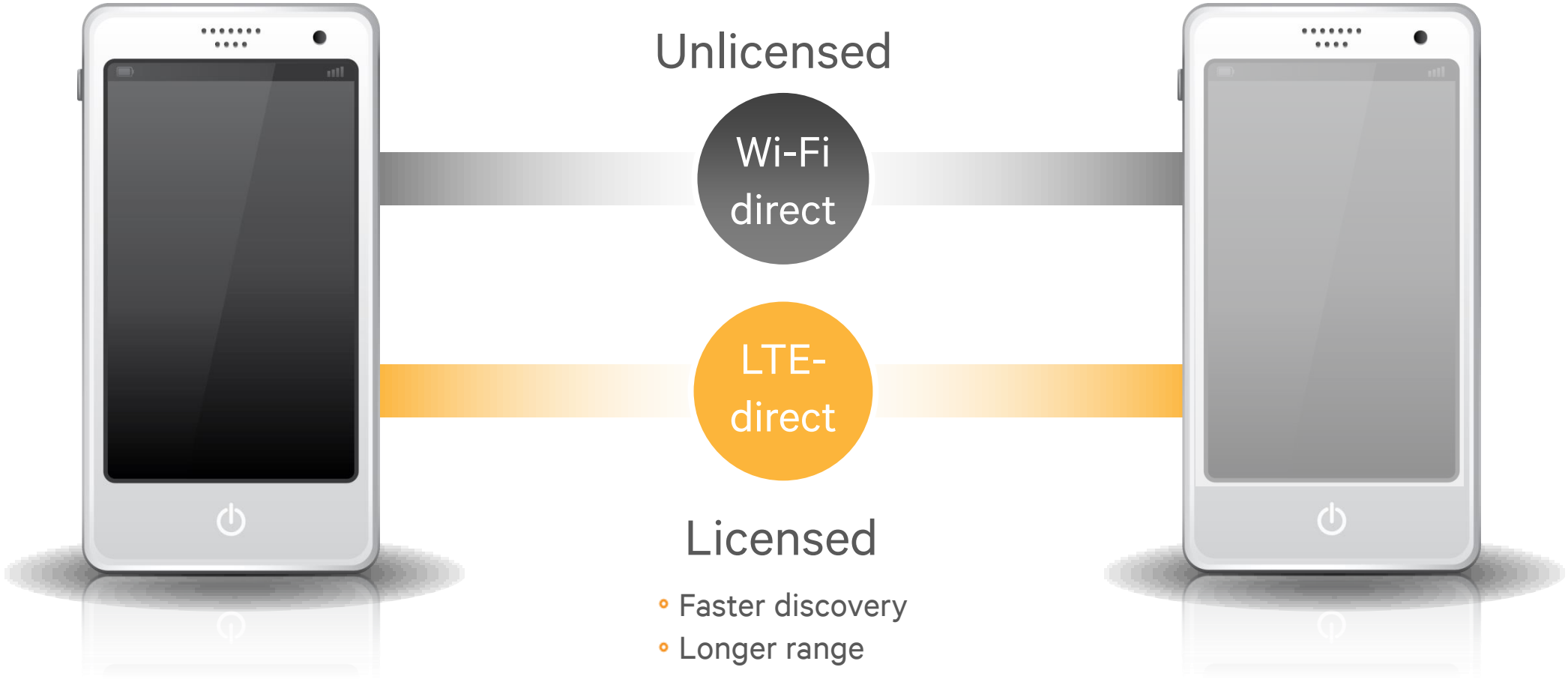


Fixed gating of background traffic (shown) → Opportunistic gating of background traffic → Opportunistic gating of delay-tolerant traffic

Qualcomm Technologies' background gating solutions is called NSRM (Network Socket Request Manager) and is part of CnE. [1]Reduced RRC signaling for a mix of application. The actual saving depends on gating timer, mix of applications and how much push notifications. In addition to fewer messages, bundling traffic also reduces overhead

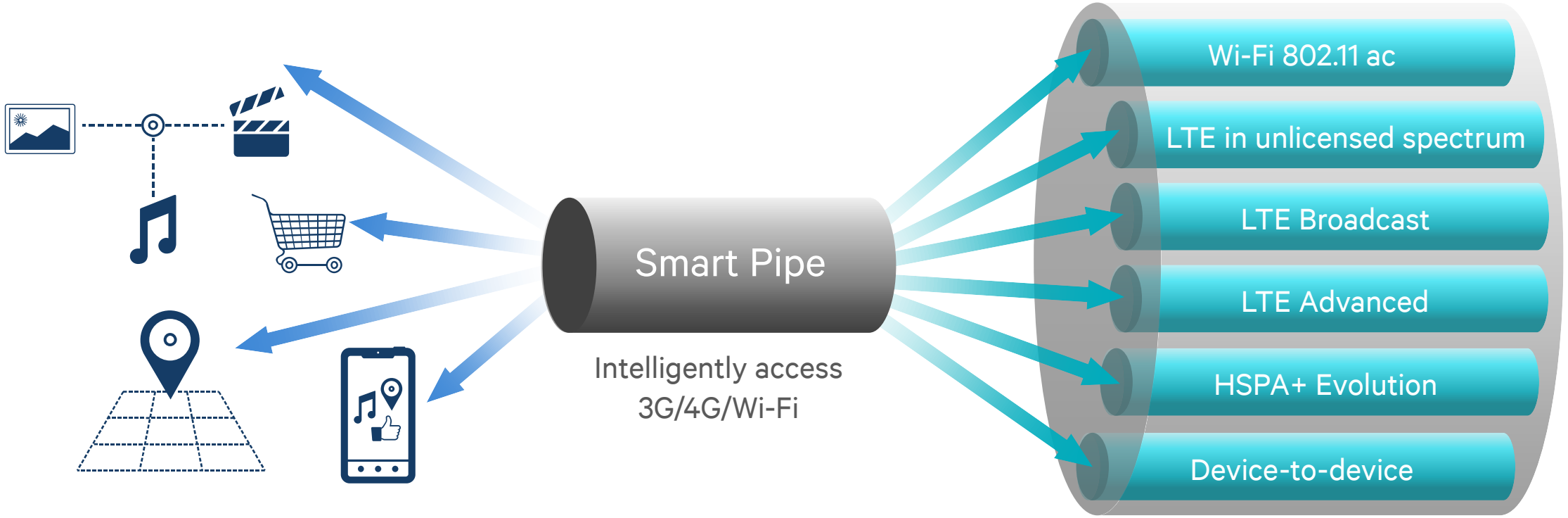
Device-to-device will enhance proximal discovery

Highly efficient, always-on local discovery and communication



Summary: we are working on multiple fronts to squeeze more capacity and value out of spectrum

1000X



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

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

Will there be 1000x demand?
It's just a matter of time...

Pushing wireless boundaries

to learn more, go to
www.qualcomm.com/1000x

- More details provided at:
  1) 1000x: More Spectrum
  www.qualcomm.com/spectrum
  2) 1000x: More Small Cells
  www.qualcomm.com/HetNets
  3) 1000x: Higher efficiency
  www.qualcomm.com/efficiency

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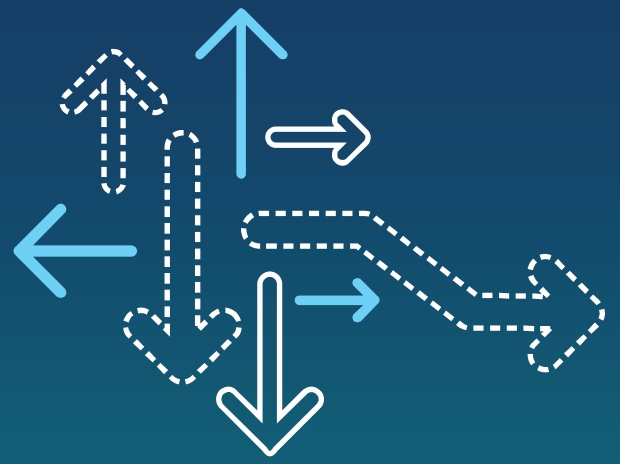

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