September 2015

Creating a Digital 6th Sense with LTE Direct
LTE Direct is creating a Digital 6\textsuperscript{th} Sense through always-on proximal discovery services

1. **Always-on device-to-device discovery of friends, services, offers in one’s proximity**
   Proximal discovery services efficiently integrated with existing LTE Advanced services and networks

2. **Required to scale up from today’s location-based and proximity beacon solutions**
   Privacy sensitive and battery efficient discovery of 1000s of devices/services in the proximity of ~500 meters

3. **LTE Direct ecosystem implementation underway – standardized in 3GPP R12**
   Operator trials ongoing; app developers testing innovative use cases today with LTE Direct Trial SDK\textsuperscript{1}

---

\textsuperscript{1} LTE Direct Trial SDK by Qualcomm Technologies limited availability through ltedirect.qualcomm.com
The next generation mobile services in a hyper-connected world
Mobile devices aware of the user and surroundings, connecting our digital and physical worlds

- Discovers
  Things relevant to you
- Senses
  Your environment and motion
- Learns
  Your preferences
- A Digital 6th Sense
- Filters
  For things relevant to you
- Knows
  You and what’s around you
- Interacts
  With your surroundings
LTE Direct Proximity Services: Always-on proximal awareness

Enabling users & mobile apps to passively interact with the hyper-connected world

Who’s nearby? What’s nearby? Is it relevant to me, now?

A shop nearby has the watch you wanted under $100

Your friend Alex is nearby
The always-on proximal discovery challenge
Scaling proximity services for mass consumer adoption

Privacy
Barriers to technologies that continuously track location

Battery Life
Always-on services require continuous proximal discovery

Scale
Long range and high capacity required to expand use cases

Interoperability
Proprietary platforms lead to mobile app silos
Proximal discovery services are expanding the reach of mobile

Utilizing technologies today that either track user’s location or proximity to nearby beacons

### Location-based app

- Tracking user’s location and access cloud to identify relevancy
  - Unlimited range
  - Large install base
  - Privacy barrier with location tracking
  - Battery drain from constant network pings
  - Proprietary platform

### Proximity Beacons (BT-LE²)

- Deliver relevant value by notifying nearby users using an associated app
  - Privacy sensitive
  - Low power consumption
  - Indoor support
  - Limited range – 10s of meters
  - Limited capacity that doesn’t scale
  - Proprietary platform

> $7B total M&A activity in proximal discovery services in 2013¹

¹ Source: BIA/Kelsey, May ‘13; ² Bluetooth® Smart (Low Energy) feature as part of the Bluetooth Core Specification version 4.0 and higher
Scaling up proximity services for mass consumer adoption

**Location-based**
Centralized Geo-fencing

**Bluetooth Beacons**
Distributed Geo-fencing

**Gaining traction** across limited use cases due to Bluetooth range and capacity, plus mobile app silos continue

**LTE Proximity Services**
Device-to-Device Discovery

- Battery efficient and privacy sensitive
- ~10x the range of Bluetooth
- Scalable to 1000s of devices/service
- Interoperable across mobile apps

**The path to mass adoption** across a wide range of use cases with discovery that is:

**Poor adoption** due to poor battery life, privacy barriers, and mobile app silos
LTE Direct is a device-to-device technology required to scale up from today’s proximal discovery solutions.
LTE Direct is solving the always-on proximal discovery challenge

**Discovery at scale**
Discovery of 1000s of devices / services in the proximity of ~500m

**Interoperable discovery**
Universal framework for discovery across apps/devices/operators

**Always-on awareness**
Privacy sensitive and battery efficient discovery without user/app intervention

**Part of global LTE standard**
Opportunities for entire mobile industry leveraging vast LTE ecosystem
Discovery with unparalleled scalability and capacity

LTE Direct enables broader set of use cases than other device-to-device technologies

<table>
<thead>
<tr>
<th></th>
<th>BT-LE</th>
<th>LTE Direct</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capacity</td>
<td>Hundreds</td>
<td>Thousands</td>
</tr>
<tr>
<td>Range (m)</td>
<td>~50 m</td>
<td>~500 m</td>
</tr>
<tr>
<td>Active Duration (ms)</td>
<td>~4000 ms</td>
<td>~75 ms</td>
</tr>
</tbody>
</table>

Proximal discovery at scale

1 Source Qualcomm Technologies simulations; Assumptions: outdoor deployment model (e.g. Farmer’s market), Ped A channel model, ITU-1411 pathloss mode, Carrier frequency of 2 GHz for LTE Direct / 2.4 GHz for BT-LE, System bandwidth of 10 MHz FDD for LTE Direct / 2 MHz for BT-LE, LTE Direct protocol implementation of 75 subframes every 18 seconds, BT-LE beacon protocol implementation of advertising for 1.318 ms every 1.20 s with <20% collision / scanning for 256 ms every 1.28 s
Battery efficient and privacy sensitive always-on awareness

LTE Direct provides enhanced user experience over location-based solutions

**Privacy sensitive**
Devices do not need to reveal their identity or allow location tracking, thus minimizing privacy barriers

**Battery efficiency**
Determining relevancy is done at the device level eliminating battery inefficient network pings

**Autonomous**
Continuously and passively proximal discovery of relevant value without user or app intervention
LTE Direct provides interoperable discovery
Vastly expanding the reach and value of proximal discovery for mobile app developers

Universal framework for discovery across apps, devices, operators

Example: Digital Out-of-Home personalizing content on digital signs based on input from audience interests/affinities
LTE Direct leverages the global LTE ecosystem

Part of 3GPP Release 12

Common global standard
Support for paired (FDD) and unpaired (TDD) spectrum
Vibrant, global ecosystem

390+ Networks in 135+ countries
2,900+ Devices from 250+ vendors

Source: GSA (www.gsacom.com) – April 2015 for networks and Feb 2015 for devices
We must make best use of all technologies for proximity services

Location-based
User-initiated search (plus navigation)
Enhance relevancy of search results through location tracking with unlimited range

LTE Direct
Always-on device-to-device proximal discovery
Privacy sensitive and battery efficient discovery of 1000s of devices / services in the proximity of ~500m

Proximity beacons
Micro-location awareness and geo-fencing
Engage customers in close proximity (~50m) with relevant, timely, and personalized content
LTE Direct provides privacy sensitive and battery efficient discovery at scale and range

How does it work?
LTE Direct: A day out at the shopping center
LTE Direct is a device-to-device proximal discovery technology
All devices can broadcast needs and services via “expressions”

Lisa via Social Match: “I like shopping!”

Coffee Shop via Food Finder: “Live music this afternoon”

Smoothie Shop via Deal Finder: “10% off your usual order”

Jamie via Friend Finder: “Looking for nearby friends”

Rob via Ticket Finder: “Tickets for game today”
Services are efficiently mapped to Expressions

Public Expressions
- Application agnostic
- Any proximal device can decode expression
- Good for advertising, local “finder” apps, etc.

Private Expressions
- Application specific
- Only proximal devices with “key” can decode expression
- Good for personal identification

Note: Private Expression mappings based on a one-way hash function with a private key and permissions controlled via specific apps
Relevance is passively identified with no user/app intervention

Optional metadata
Additional info available following discovery (e.g., street address)

2 new alerts!

Your friend Jamie is nearby!

10% off your smoothie!

Relevant Expressions
10110000011101010...
10001110111100010...

Filtered Expressions
01100000111011111...
10010000010101111...
11110001010001111...

Relevancy is determined at device level

Sale @ Smoothie Shop
10001110111100010....

Jamie @ Friend Finder
10110000011101010...
Communication via traditional LTE or Wi-Fi/Wi-Fi Direct

we r nearby. wanna meet for coffee?

Text Jamie
LTE Direct efficiently utilizes LTE spectrum for discovery

Leverages LTE infrastructure
For timing, resource allocation (to LTE Direct), as well as user authentication

LTE RAN:
Timing, Configuration, Authentication, Communication

LTE Air Interface:
Discovery

Uses LTE licensed spectrum
Uplink resources in LTE FDD system or dedicated frames in LTE TDD system

Negligible impact to capacity
Utilizes <1% of uplink resources

1 Source: Qualcomm simulations; Assumes 20MHz system with ~2,000 expressions
LTE Direct resources are managed by mobile operators

1 Assumptions: 1 Expression = 2 LTE Resource Blocks (RBs); 88 RBs used for discovery in 20MHz FDD system that uses 64 sub-frames @ 1ms each, every 10 seconds
LTE Direct ecosystem implementation is underway creating opportunities for the entire mobile ecosystem
Empowering new experiences across a wide range of use cases

**Continuous Discovery**
- of relevant people, products, services, events

**Social Discovery**
- of friends, colleagues, dates, ...

**Retail Discovery**
- of merchants, products, ...

**Event Discovery**
- of music, sporting, ...

**Service Discovery**
- of restaurants, transportation, ...

**Personalized Interactions**
- with the user’s surroundings and environment

**Loyalty Programs**
- personalizing services and offers

**Reverse Auctions**
- personalizing promotions

**Digital Out-of-Home**
- personalizing digital signs

**Personalized Services**
- personalizing experiences, e.g. at a venue

Based on the users interests/affinities
LTE Direct creates opportunities for the entire ecosystem

- **Mobile Operators**
  - Access to LTE Direct Proximity Services

- **OEMs & ASPs**
  - New and enhanced user experiences

- **Mobile Subscribers**
LTE Direct is managed and monetized by mobile operators

**Service Access**
Monetize API access to mobile app developers for utilizing LTE Direct Proximity Services

**Mobile Advertising**
Monetize interest by commercial advertisers to pay for proximity-based consumer notifications

**Data Mining**
Monetize consumer-approved, anonymized data on consumer interests that are broadcasted and filtered with LTE Direct Proximity Services

---

1 Source: Qualcomm simulations; Assumes 20MHz system with ~2,000 expressions
Achieving scale requires discovery between mobile operators

Option 1

Operator A Uplink or TDD

Operator B Uplink or TDD

Broadcast and listen to expressions on their own spectrum
Listen-only on other operator’s spectrum

Option 2

All devices in a country/region broadcast and listen to LTE
Direct expressions on the same agreed-upon spectrum band(s)
LTE Direct empowers app providers and OEMs to differentiate

Lead the next generation of mobile proximity services through a differentiated user experience

**Discovery at scale**
Discovery of 1000s of devices / services in the proximity of ~500m

**Always-on awareness**
Privacy sensitive and battery efficient discovery without user/app intervention

**Interoperable discovery**
Universal framework for discovery across apps/devices/operators

Solving the always-on proximal discovery challenge
Implementation of the LTE Direct ecosystem well underway

**Standardization**
by 3GPP as a feature in Release 12

- System Architecture and RAN specification complete
- RF performance and conformance forecasted to be complete

**Operators Trials**
launching across multiple regions

- Technical Trials completed with Deutsche Telekom (Germany) & KT Corp. (Korea)
- Large Scale User trials planned in China, US and Japan
- Trials supported by multiple infrastructure vendors and device OEMs

**App Developers**
engaging on use case development

- Developing use cases leveraging trial SDK by Qualcomm Technologies
- Early developers include Facebook, Yahoo, Control Group, R/GA, Sacramento Kings, M-87, Compass.TG, and more
LTE Direct is evolving to bring new ways to connect & interact

**Release 12**
D2D platform for consumer and public safety use cases

- Discovery of 1000s of devices/services in ~500m
- Reliable one-to-many communications (in- and out-of-coverage)*

**Release 13**
Expanded D2D discovery and D2D communications

- More flexible discovery such as out-of-coverage and multi-carrier
- Device-to-network relays*

**Release 14 and beyond**
Multi-hop communication and more use cases

- Additional D2D communication capabilities
- Proposed for vehicle-to-vehicle (V2V)

* Designed for Public Safety use cases
LTE Advanced is evolving and expanding into new frontiers

Scaling to connect the Internet of Everything

Bringing new ways to connect & interact

Empowering new classes of services

Creating a converged connectivity platform

Carrier Aggregation
High performance
Ultra efficient
Cat-0, LTE-M

Evolving the LTE Direct Platform
Device-to-Device
Multi-hop
Vehicle-to-Vehicle / Infrastructure

Mission-critical control
LTE ULL
Broadcast
LTE Broadcast
Discovery
LTE Direct Proximity

Public Safety
LTE Direct MCPTT

Link aggregation
Converged LTE + Wi-Fi
Converged spectrum solutions
Converged deployment models
LTE-U and LSA
Neighborhood small cell
LTE Direct is creating a Digital 6\textsuperscript{th} Sense through always-on proximal discovery services

1. **Always-on device-to-device discovery of friends, services, offers in one’s proximity**
   Proximal discovery services efficiently integrated with existing LTE Advanced services and networks

2. **Required to scale up from today’s location-based and proximity beacon solutions**
   Privacy sensitive and battery efficient discovery of 1000s of devices/services in the proximity of ~500 meters

3. **LTE Direct ecosystem implementation underway – standardized in 3GPP R12**
   Operator trials ongoing; app developers testing innovative use cases today with LTE Direct Trial SDK\textsuperscript{1}

**Learn more at:**
www.qualcomm.com/lte-direct
Questions? - Connect with Us

www.qualcomm.com/wireless

www.qualcomm.com/news/onq

@Qualcomm_tech

http://www.youtube.com/playlist?list=PL8AD95E4F585237C1&feature=plcp

http://www.slideshare.net/qualcommwirelessrevolution
Thank you

Follow us on: f /twitter /linkedin /tumblr

For more information, visit us at:
www.qualcomm.com & www.qualcomm.com/blog

©2013-2015 Qualcomm Technologies, Inc. and/or its affiliated companies. All Rights Reserved.

Qualcomm is a trademark of Qualcomm Incorporated, registered in the United States and other countries, used with permission. AllJoyn is a registered trademark of the AllSeen Alliance. Other product and brand names may be trademarks or registered trademarks of their respective owners. All trademarks of Qualcomm Incorporated are used with permission. Other products and brand names may be trademarks or registered trademarks of their respective owners.

References in this presentation to “Qualcomm” may mean Qualcomm Incorporated, Qualcomm Technologies, Inc., and/or other subsidiaries or business units within the Qualcomm corporate structure, as applicable.

Qualcomm Incorporated includes Qualcomm’s licensing business, QTL, and the vast majority of its patent portfolio. Qualcomm Technologies, Inc., a wholly-owned subsidiary of Qualcomm Incorporated, operates, along with its subsidiaries, substantially all of Qualcomm’s engineering, research and development functions, and substantially all of its product and services businesses, including its semiconductor business, QCT.