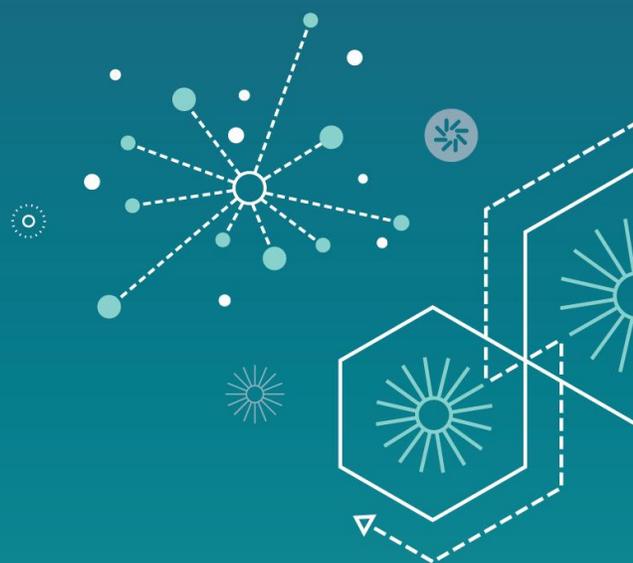


LTE Direct Always-on Device-to-Device Proximal Discovery

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1 Executive summary

LTE Advanced is shaping up to be a pervasive technology that not only meets the ever-increasing data demand to solve [the 1000x challenge](#), but also expands into new frontiers, be it unlicensed spectrum, converging terrestrial and mobile broadcast, or enabling new applications/services such as LTE Direct device-to-device proximal discovery. This paper discusses an early indicative example of LTE Advanced expansion, LTE Direct, and highlights the many dimensions of benefits this innovative new technology brings to the entire mobile industry in helping to achieve the vision of creating a Digital 6th Sense.

So, what exactly is this vision of creating a Digital 6th Sense? Mobile has already revolutionized the telephony and computing industries, providing voice and data services with seamless mobility to approximately 7 billion connections worldwide. The next generation of mobile services is taking advantage of this hyper-connected world to empower mobile devices and applications to create a Digital 6th Sense through always-on awareness of the user's surroundings. This next generation of services will seamlessly connect people's physical worlds with their digital worlds, establishing disruptive new mobile services that are poised to transform industries such as Health, Education, Retail, and Advertising.

Proximal discovery is at the core of this transformation, empowering mobile devices and applications to passively and continuously discover friends, offers, and other relevant value in one's proximate physical world based on the 'affinity monitors' set up by consumers in their mobile applications. Much more than just a 'friend finder', proximal discovery establishes a paradigm shift from the Personal Computer (PC) 'search-to-discover' mindset, to always-on discovery services that are fundamental to defining the next generation of mobile services across an extensive set of use cases.

Providing always-on proximal discovery is a significant challenge for the mobile industry. Today's existing approaches, utilizing either location-based technologies or *Bluetooth*® Low Energy (BT-LE) proximity beacons, provide excellent solutions for specific use cases, but fall short of providing scalable, always-on proximal discovery services in a battery efficient and privacy sensitive manner. LTE Direct is a device-to-device proximal discovery technology that is required to scale up from today's existing solutions, creating a true Digital 6th Sense by providing always-on proximal discovery services with a common language for discovery across mobile apps, devices, and operating systems. LTE Direct is defined as part of the upcoming Release 12 of the 3GPP standard, and it can be efficiently integrated with existing LTE Advanced services and networks.

Qualcomm, with its demonstrated ability to push wireless boundaries, is at the forefront of LTE evolution, not only envisioning, but also inventing, developing and commercializing technologies that bring our vision to fruition. Our being first to commercialize 3G/LTE multimode and now LTE Advanced (carrier aggregation) are vivid and recent proof-points of such thought leadership. Qualcomm Technologies is one of the main contributors to LTE Advanced standards development and was among the first to prototype and demonstrate the benefits of LTE Direct. We are continuing to work closely with industry partners to build out the LTE Direct ecosystem including operator trials throughout 2014 and enabling app developers to create and test use cases with a trial LTE Direct Software Development Kit (SDK) by Qualcomm Technologies.

2 Expanding mobile services with always-on proximal discovery

Everyone has experienced serendipitous moments; the fortunate happenstance of running into a long-time friend...the pleasant surprise of stumbling upon an amazing offer...the lucky discovery of a nearby event that would have been a big disappointment to miss. But what if this phenomenon of discovering value in one's physical proximity was not left to chance? What if mobile devices and mobile apps continuously and passively were on the lookout for that chance encounter or once-in-a-lifetime offer?

Proximal discovery will empower the next generation of mobile apps to create a Digital 6th Sense through always-on awareness of friends, services, offers, and other relevant value in one's proximity. Apps using proximal discovery will enable users to be aware of what's happening around them at all times, effortlessly and privately, changing how people socialize, get discounts and interact with people and things, as shown in Figure 2.1.



Fig. 2.1: Always-on proximal discovery of relevant value in one's proximity

2.1 The opportunity for proximal discovery

Proximal discovery is a multibillion dollar opportunity for the entire mobile ecosystem across an extensive set of use cases including social searching/matching, venue specific services, proximity triggered loyalty services/authentication, push advertising, and many more. Everyone has a need to discovery something, and always-on proximity services allow each individual to be perpetually on the lookout for whatever social or affinity interests he/she is partial to.

Social Networking Services (SNS) are all about connecting people through content and discovering content through people. As shown in Figure 2.2, a key recent trend for social networking is Applications Services Providers (ASPs) utilizing proximal discovery for social matching (e.g., 'friend finder', 'date finder'), interest matching (e.g., 'find a tennis partner'), or even shared experience (e.g., at a sporting event or concert).

In advertising, retailers are looking to leverage mobile to increase the relevancy of their advertising spend with location-targeted mobile advertising. Over 80% of smartphone shoppers use their devices to help shop while in a store³. As Figure 2.3 shows, retailers are shifting more and more of their advertising spend to location-targeted mobile advertising.

Beyond SNS and advertising, there is a broad range of potential use cases that are contributing to industry enthusiasm and activity in proximal discovery



Fig. 2.2: Large proximal discovery opportunity in Social Networking Services



Fig. 2.3: Shift in advertising spend by retailers to location-targeted mobile advertising

1 Source: Smith's Point Analytics, Feb' 13; 2 Source: BIA/Kelsey, May '13; 3 Source: Google, Apr. '13

services. Consumers could be alerted to nearby scarce services or events (e.g., concerts) they are passionate for; an employee's access to sensitive records could be restricted to no more than 200 meters from the office; mobile games could integrate elements of the physical world (e.g., scavenger hunts); a hotel could know when its best customers walk through the door; a tourist could remain continuously notified of nearby items of interest;. The list – and the vision – goes on and on.

2.2 The always-on proximal discovery challenge

For Original Equipment Manufacturers (OEMs) that build mobile devices and Application Service Providers (ASPs) that build mobile applications, delivering always-on proximal discovery services requires solutions to difficult challenges in order to scale proximity services for mass consumer adoption. These challenges can be grouped into four major categories:

1. Battery drain from proximal discovery services continuous operation
2. Scale to cover long enough ranges and high enough capacity to enable broad set of use cases
3. Interoperable discovery between different mobile apps, operating systems, devices, etc.
4. Privacy barriers to approaches that perpetually track the user's location

Battery drain is a critical consumer pain point hindering adoption of always-on proximal discovery services that are continuously waking up to discover value in one's proximity. App developers require solutions that efficiently discover numerous proximal resources in a minimal amount of time so that the device can quickly return to sleep without impacting battery life.

The value of proximal discovery services is also heavily impacted by how effective these services are at detecting relevant value based on the 'affinity monitors' set up by consumers in their mobile applications. The value of these proximal discovery services can be negatively impacted if the range or discovery capacity (number of 'things' that can be discovered) is constrained based on technology limitations. Furthermore, when a consumer expresses an 'affinity monitor' in a specific mobile app, the value of the service severely diminishes if proximal discovery is limited to only that application–interoperable discovery is needed to avoid proprietary platforms that lead to mobile app silos.

Finally, approaches to proximal discovery that rely on perpetually tracking user's location pose significant privacy concerns for the consumer. A recent study conducted by Microsoft in a number of countries emphasizes this consumer sentiment about location services and privacy. Of the 1,500 people surveyed, 84% stated that they were concerned about location sharing without their consent and 52% expressed concern with sharing their location with other people and organizations.

2.3 Today's existing approaches to proximal discovery

Today's existing approaches, utilizing either location-based technologies or BT-LE proximity beacons, provide excellent solutions for specific use cases, but fall short of providing scalable, always-on proximal discovery services.

Location-based approaches continuously track the user's location to determine proximity and use a centralized, cloud-based approach to identify relevancy. A server that is associated with a specific mobile app receives periodic location updates from user mobile devices and delivers proximal discovery based on location updates and interests. As seen in Table 2.1, location-based approaches have the advantages of unlimited range and a large install base in mobile devices, but privacy and battery life issues due to perpetual location tracking and constant network pings to access the cloud. This makes location-based approaches excellent for increasing the relevancy of user-initiated searches (e.g., 'find me a restaurant'), but limited in providing continuous and passive proximal discovery services.

Proximity beacons, on the other hand, utilize device-to-device discovery to deliver relevant services to nearby users through an associated mobile app. As also seen in Table 2.1, this overcomes the privacy and battery life concerns of location-based approaches. However, proximity beacons are based on *Bluetooth®* Low Energy connectivity that operates in unlicensed spectrum. These beacons broadcast services to nearby users in a range of only approximately 50 meters limiting the type of use cases that can leverage this approach. Also, proximal discovery services based on device-to-device technologies that operate entirely in unlicensed spectrum do not scale well; battery life increases exponentially as the number of users increases. This is primarily due to uncontrolled interference and a lack of synchronization between user's devices. Despite these limitations, proximity beacons are an excellent approach for providing micro-location awareness and geo-fencing for those applications where the range and capacity of BT-LE are not limiting (e.g., inside a retail store).

 <p>Location-based approaches</p>	 <p><i>Bluetooth®</i> Low Energy Proximity Beacons</p>
<ul style="list-style-type: none"> + Unlimited range + Large install base - Battery drain from constant network pings - Privacy barrier with location tracking - Proprietary platform leads to mobile app silos 	<ul style="list-style-type: none"> + Lower power consumption + Privacy sensitive + Indoor support - Limited range of ~50 meters - Limited capacity that doesn't scale - Proprietary platform leads to mobile app silos

Table 2.1: Limitations of existing proximal discovery approaches

3 LTE Direct: Solving the always-on proximal discovery challenge

LTE Direct is an innovative device-to-device discovery technology that is required to scale up from today's existing proximal discovery approaches. LTE Direct is part of the rapidly growing and global LTE ecosystem with over 300 LTE networks in over 110 countries, and over 1,500 global LTE devices from over 100 different vendors⁴. It will be part of the upcoming Release 12 of the 3GPP standard. LTE Direct incorporates multiple dimensions of enhancements which can be grouped into three major categories:

1. Device-to-device discovery at unparalleled scale and capacity – discover 1000s of devices/services in ~500 meter proximity
2. Battery efficient and privacy sensitive always-on awareness – determine relevancy at the device level without user/app intervention and without revealing the user's location
3. Interoperable discovery across apps, operating systems, devices, and operators – provide a simple, universal framework for discovery

By providing “always-on” proximal discovery in a privacy sensitive, battery efficient, and scalable manner, LTE Direct enables a differentiated user experience that consumers can adopt at a much larger scale.

3.1 Discovery at scale

LTE Direct is a device-to-device discovery service operating in licensed spectrum. LTE Direct enables service layer discovery to mobile applications. Mobile applications can instruct LTE Direct to monitor for mobile application services on other devices and can also broadcast their own services. All LTE Direct-enabled devices can broadcast their needs and services via a beacon on a periodic basis (e.g., every 10 seconds). This beacon is called an ‘Expression’ in LTE Direct. Expressions are 128-bit service-layer identifiers that represent many different things, such as an identity, a service, an interest, or a location. These expressions are broadcasted for all devices in proximity to listen to utilizing LTE spectrum.

LTE Direct uses the uplink resources in a LTE FDD system and dedicated frames in a LTE TDD system. It leverages the LTE network for timing, resource allocation, as well as user authentication. As shown in Figure 3.1, LTE Direct works seamlessly with LTE, setting aside a small percentage of sub-frames for efficient discovery. All LTE Direct-enabled devices “wake-up” synchronously during these sub-frames and either broadcast or listen for expressions. LTE Direct can be efficiently integrated with existing LTE Advanced services and networks with minimum capacity impact to traditional broadband services, utilizing less than 1% of the uplink resources⁵.

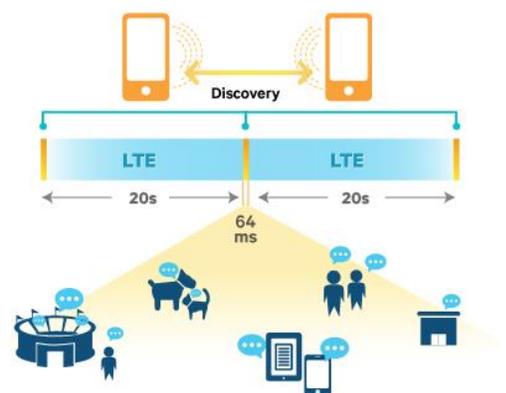


Figure 3.1: LTE Direct efficiently integrated with LTE Advanced

4 Source: www.gsacom.com, March 2014;

5 Source: Qualcomm Technologies simulations; Assumes 20MHz system with ~2,000 expressions

In our increasingly hyper connected world, it is an immense challenge to quickly and efficiently discover the people, services, and things that are most relevant to you. Capitalizing on the predictable performance of licensed spectrum, LTE Direct delivers discovery at scale, overcoming the range and capacity limitations of other device-to-device technologies, such as BT-LE proximity beacons. As shown in Table 3.1, LTE Direct also leverages the tightly controlled LTE network to synchronously 'wake-up' all devices for efficient discovery, minimizing the active duration of the discovery period before returning to 'sleep', thus reducing power and extending battery life.

	BT-LE	LTE Direct
Discovery Density (# of devices covered)	Hundreds	Thousands
Range (m)	~50	~500
Active Duration (ms) ¹	~4000	~75

Table 3.1: LTE Direct has unparalleled scalability and capacity versus other device-to-device technologies

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 sub-frames every 18 seconds, BT-LE beacon protocol implementation of advertising for 1.518 ms every 1.20 s with <20% collision / scanning for 256 ms every 1.28 s

3.2 Always-on awareness

The existing location-based proximal discovery approach is a cloud-based paradigm and is based on the application perpetually tracking the user's location and comparing it against a database of what is in the vicinity. This requires constant network pings that drain battery life and creates a significant privacy barrier to mass consumer adoption.

LTE Direct is an alternative for mobile developers seeking to deploy proximate discovery solutions as extensions of their existing cloud services. As shown in Figure 3.2, LTE Direct is a distributed discovery solution - apps forego centralized database processing in identifying relevancy matches. They instead autonomously determine relevance by filtering the 128-bit Expressions (service layer identifiers that are being broadcasted in their proximity) at the device level by monitoring for relevant attributes. Because relevancy is efficiently determined at the device level, LTE Direct eliminates costly network pings that drain battery life with cloud-based approaches. Furthermore, LTE Direct discovery is connectionless and is only based on proximity, allowing the devices to discover others without revealing their own identity or exact location.



Figure 3.2: LTE Direct passively filtering for relevancy at the device level

LTE Direct-enabled devices can listen to 1000s of expressions in proximity of ~500 meters each time they wake up for discovery (e.g., every 10 seconds). It is therefore critical to provide efficient filtering of the 128-bit Expressions for relevancy to ensure users only get alerted of hyper-relevant proximal value. This filtering is done at the physical layer allowing the applications to be closed while LTE Direct continuously works to

determine relevancy and notify the application when it detects a match to the monitor it set. Expressions utilize a minimal amount of information to be discovered analogous to a subject line of an email; additional associated information may be accessed when/if a relevancy match is made.

3.3 Interoperable discovery

LTE Direct provides a common language for discovery; it operates horizontally across apps, operating systems, devices, and operators, exponentially expanding the field of value for proximal discovery. LTE Direct expressions can be private and discreet (targeted securely for certain audiences only) or public (transmitted so that any application can receive them). Public expressions are a common language available to any application to discover each other, and this is the foundation to providing interoperable discovery.

Public expressions exponentially expand the field of value for proximal discovery. For example, someone using Facebook to monitor for an affinity for "photography" may find a new photography exhibit opening being broadcasted via Yelp over LTE Direct, a Senior Vice President of photography at ESPN being broadcasted via LinkedIn, or another person interested in photography being broadcast via Twitter. Public expressions combine all applications - all value - into one single network, thereby expanding utility of system.

Services are efficiently mapped to Public Expressions through a hierarchal mapping that is centrally managed by an Expression Name Server (ENS). The ENS contains a hierarchy of interest categories for expressions that the mobile apps can utilize to map their services to Public Expressions in a structured and efficient manner.

3.4 Making the best use of all proximal discovery technologies

LTE Direct proximal discovery is not intended to replace existing proximal discovery approaches, but instead co-exist with these approaches extending the ecosystem by providing additional value to mobile users. As seen in Figure 3.3, location-based solutions will remain the solution of choice for providing enhanced search results utilizing the unlimited range of location technologies (e.g., user searching for nearby coffee).

Proximity beacons will remain an excellent approach for providing micro-location awareness and geo-fencing for those applications where the range and capacity of BT-LE are not limiting (e.g., inside a retail store). LTE Direct scales up the user experience by providing always-on proximal discovery with the privacy, battery efficiency, range, and capacity to enable mass consumer adoption through an enhanced user experience.



Figure 3.3: Making the best use of all technologies for proximity services

4 LTE Direct benefits the entire mobile industry

LTE Direct is poised to create big opportunities for the entire mobile industry as shown in Figure 4.1. LTE Direct uses licensed spectrum, providing operators an unprecedented opportunity to monetize services beyond voice and data. Its potential for application development is huge, with possibilities extending to social discovery, advertising, gaming, education, emergency services and much more. LTE Direct's enhanced user experience gives mobile Application Service Providers (ASPs) and Original Equipment Manufacturers (OEMs) an opportunity to differentiate and lead in the next generation of mobile services.



Figure 4.1: LTE Direct benefits the entire mobile industry

4.1 A unique opportunity to monetize new services for mobile operators

Mobile operators are the global spectrum holders for LTE Direct, authorizing and controlling access to the system. Multiple business models are possible to the mobile operators to leverage this opportunity in proximal discovery services. Potential business models include:

- **User subscription:** Mobile operators charge users a nominal monthly fee to access LTE Direct proximal discovery services. The users benefit from the enhanced user experience of LTE Direct versus other proximal discovery approaches.
- **API access fees:** Mobile operators charge Application Service Providers (ASPs) a fee for access to the LTE Direct APIs. API access fees is an established and existing business model, with ASPs paying for everything from access to map APIs to APIs to manipulate the camera hardware on the mobile device. ASPs benefit from high user adoption due to enhanced user experience, as well as significant cost and Human Resource savings compared to the complex server infrastructure required with cloud-based approaches.
- **Value-added services:** Mobile operators can also stack services such as proximity-based advertising on top of LTE Direct proximal discovery services. Retailers have a significant need for proximity-based advertising solutions. The reach, scale, and privacy benefits of LTE Direct make it an ideal technology for proximity-based advertising.

These potential models create a unique opportunity for mobile operators to monetize services beyond traditional voice and data services. And because LTE Direct utilizes a very small percentage of mobile operator's LTE spectrum, these additional services may be offered without any significant impact to capacity for existing voice and data services. It is important, however, that operators not bundle all services from day one, but instead layer additional services as the LTE Direct technology gains traction.

4.2 Achieving interoperability between mobile operators

One additional consideration for mobile operators is delivering interoperability between different operators in a specific region operating on different LTE spectrum (frequency) bands. In order for mobile operators to fully scale LTE Direct proximal discovery services and provide maximum value to ASPs, this interoperability is critical. Interoperability can be achieved in multiple ways:

1. As seen in Figure 4.2, by allowing devices from Operator A to tune to Operator B's spectrum to listen to announcements from Operator B's LTE Direct devices during discovery. Operator A's devices transmit its announcements in Operator A's spectrum.

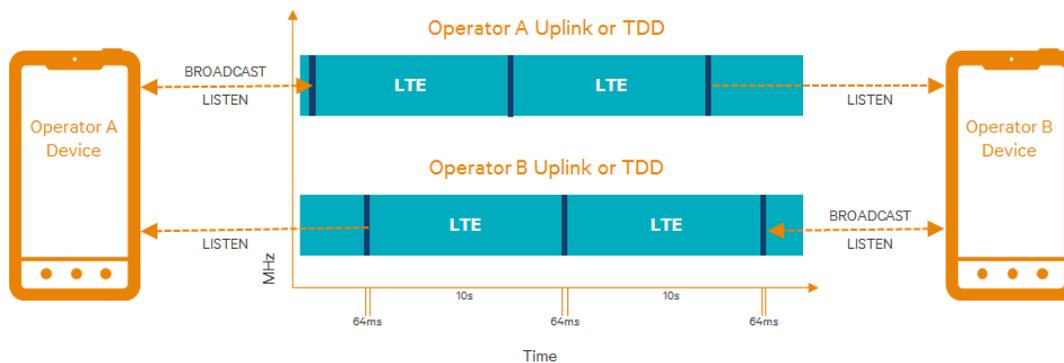


Figure 4.2: Achieving interoperability between mobile operators

2. By enabling all devices in a country/region to transmit and receive announcements on the same LTE spectrum band(s) that is agreed to by all of the operators in that country/region.

A key element involves the business agreements that need to be in place to enable interoperability. This may appear to be a difficult hurdle to cross, but the success of SMS text messaging is proof that successful cross-operator business agreements to enable interoperability are possible.

4.3 An opportunity to differentiate for OEMs and ASPs

In the increasingly competitive environment of mobile apps – where mobile users download 50+ apps but regularly only use a handful – adoption costs of battery life and privacy are a decisive differentiator. This is paramount to the decision making process of app developers as they decide on proximate discovery capabilities. LTE Direct's enhanced user experience gives mobile app developers and OEMs an opportunity to differentiate and lead in the next generation of mobile services.

5 Conclusion

LTE Advanced is shaping up to be a pervasive technology with solutions that not only meet the ever-increasing data demand of traditional mobile broadband services, but also extend its influence into many new horizons, be it new industries, new applications/services or new, unexplored spectrum bands. LTE Direct is an early indicative example of such upcoming transformation, providing device-to-device proximal discovery services that overcome the limitations of today's existing approaches to allow always-on proximal discovery in a battery efficient, privacy sensitive, and scalable manner. LTE Direct proximal discovery will empower the next generation of mobile apps to create a Digital 6th Sense making users aware of what's happening around them at all times, effortlessly and privately, changing how people socialize, get discounts and interact with people and things.

Implementation of the LTE Direct ecosystem is underway with standardization being finalized in 3GPP release 12, expected to be complete late 2014. Operator trials have begun with first trial being announced at MWC 2014 (Mobile World Congress) and additional trials planned through 2014. Application Service Providers have also begun creating and testing innovative use cases, leveraging the trial LTE Direct SDK by Qualcomm Technologies available at ltdirect.qualcomm.com.

The stakes are extremely high for defining the next generation of mobile services. Proximal discovery applications are emerging as a huge opportunity with a wide range of use cases. Social matching, push advertising, gaming, loyalty services, credentialing, and auto authentication are just a few examples. LTE Direct creates opportunities for the entire mobile industry to lead in the next generation of proximity services by allowing a differentiated, always-on proximal discovery experience.

To get most updated information about LTE Direct, please visit www.qualcomm.com/lte-direct

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“We are participating in this trial because LTE Direct promises new opportunities in the mobile ecosystem.”

– *Thomas Kiessling*
Chief Product and Innovation Officer at Deutsche Telekom

“We're excited to be bringing to life the frictionless user experiences we all expect of the future, but that have not been possible with today's proximity and geo-location technologies.”

– *Colin O'Donnell*
Founding Partner, Control Group