EXPANDING YOUR HORIZONS WITH LTE DIRECT

ENABLING THE NEXT GENERATION OF PROXIMAL SERVICES

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Prepared by
Signals Research Group

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On behalf of Qualcomm, Signals Research Group researched the prospect of LTE Direct. We leveraged informal discussions that we've had with LTE Direct early adopters over the last several months, publicly-available information that we obtained on the Internet and conversations with Qualcomm to make sure that our understanding of the technical issues is correct.

As the sole authors of this paper, we stand fully behind the opinions that are presented in this paper. In addition to providing consulting services on wireless-related topics, including performance benchmark studies, Signals Research Group is the publisher of the Signals Ahead research newsletter (www.signalsresearch.com).

Executive Summary

Key highlights from this whitepaper

Wireless networks have historically communicated via a hub-and-spoke type of architecture. Whether you are on Wi-Fi, LTE or some other cellular technology, you are most likely communicating via a cell site or access point into the network. Changes are afoot. With more computing and routing power becoming available at the edge of the network, it is becoming possible for our devices to connect and be aware of the network at all times and communicate like humans do – in a personal and proximal way. LTE Direct (LTE-D) leverages the use of licensed spectrum and the global LTE ecosystem to enable powerful device-to-device proximity services that have not been easily available in existing technologies. In addition to giving the control to the end user, LTE-D has extensive range and it operates seamlessly with existing mobile network operator spectrum allocations. Equally important, it facilitates a host of new services that commercial carriers and third party mobile app developers can offer. This new type of proximity service can be looked at in two major interaction models. The first is a person-to-business or environment connection. Hyper-local advertising beacons for Etsy, Groupon, Amazon Local, Living Social, Google Offers, and Facebook Deals have created an entirely new, personalized way of doing business that relies on proximity services. The second general interaction model is person-to-person via social networking services that are interested in the interaction they can create and act on in real time for connecting people who have common interests. LTE-D will also help enable a more decentralized network architecture where mobile edge routing can be utilized for the best possible network connection. Rather than having an unmanaged beacon, both the user and mobile network operator can determine who, what, when, where, or how they want to interact with people and businesses. LTE-D performance attributes are markedly superior to competing technologies on the market, plus LTE-D benefits from the established global commercial LTE footprint provide by mobile network operators. Like all emerging technologies, there are challenges that still need to be addressed, but if the industry is willing to work together, the prospects for LTE-D are promising.

LTE-D, just like LTE, is standards based and part of the international 3GPP standards.

LTE-D is part of the 3GPP international standards that has 7.5 billion connections and nearly 4 billion users globally driving its development. Currently LTE-D, known as Proximity Services or ProSe, is defined in Release 12 of 3GPP. Mobile communications have primarily worked within the confines of the network where a phone communicates with a cell site, which is connected to a core network. LTE-D is a device-to-device (D2D) technology that truly enables a device to detect another device within its proximity directly. The network interactions for LTE-D are minimal and used for things such as authentication, synchronization and device capabilities. Further enhancements to LTE-D for public safety, vehicle-to-vehicle (V2V) communications and off network communications are targeted for future releases of 3GPP and are not the focus of this paper. Another aspect that makes LTE-D unique is the equally optimistic opportunity it brings to the mobile network operators, vendors, mobile app developers, advertisers and consumers who utilize this technology. The promise of a mobile proximity aware technology that offers better privacy, battery life, scalability and interoperability than any existing proximal technology is quite an impressive feat to achieve.

Proximity and Location are different from each other.

First though we must acquaint ourselves with the concept of location and proximity. These terms are often used interchangeably but within the context of this research they are wholly different. Location can be defined as a place or position.[1] We often refer to this in practical terms like a street address or via latitude and longitudinal coordinates. Moving from one place to another requires knowing your location. Proximity is defined by nearness in place, time, order, occurrence or relation. My proximity to someone or something else is really based on my relation to that someone or something and not a discrete location. LTE-D brings these concepts together to create proximal location awareness so that *you* can now determine, as opposed to the network, where you are in proximity to others by nearness in place, time, order, occurrence *and* relation.

1 Definitions from www.dictionary.com

The impact of LTE-D on Operator Networks

The impact of LTE-D on system performance is relatively minimal.

For mobile network operators there are several features that are beneficial to them and their customers. LTE-D operates in the uplink of the licensed LTE spectrum[2] that the operator is using, regardless of the spectrum allocation since LTE-D supports both FDD and TDD allocations. The heavily loaded downlink in the macro network is protected by using the uplink channels and timeslots. A LTE-D modified eNodeB will be configured to *not* schedule uplink data during LTE-D discovery. Although this approach seems like it would have a significant impact on capacity issues, the overall strain is relatively low on the network as a whole with less than 1% uplink utilization on a single LTE channel. The impact is minimized due to the fact that LTE-D discovery requires only a small amount of data exchange to work properly. Additionally, the RAN provides timing to all LTE-D devices so that their uplink transmissions are all synchronized and scheduled at the same time so that they can discover and find each other. The LTE network also provides configuration information and authentication services for the mobile device or UE (user equipment).

System impacts to overall network resources in the cells that have LTE-D users have shown promising results. The first system trials with Deutsche Telekom in Bonn Germany showed that implementing LTE-D discovery used about 4.1% of the uplink resources and the downlink throughput in the cell was reduced by less than 1.2%. The trial utilized only one of Deutsche Telekom's bands, the 2600 MHz Band 38 allocation, which in their case is a single 5 MHz TDD channel. It should be noted that this was done using *pre-Release 12* devices and infrastructure – the commercial implementation will have a few changes to further optimize deployment. One of the major changes that is new in 3GPP Release 12 is discovery signal implementation – the discovery is fixed to two physical resource blocks (e.g. 20 MHz has 100 PRBs) and one sub-frame. With these continued enhancements that are being introduced as part of Release 12, it is expected that the actual impact on commercial LTE network performance will likely be less than 1% on the uplink and 0.1% on the downlink. More system efficiencies can be found too if mobile operators can harmonize their LTE-D deployments on a common band or bands to use for regional and global proximity services.

By utilizing spectrum that is licensed to the network operator, the network operators can control the devices and beacons that can access that spectrum. This crucial differentiation from unlicensed technologies gives LTE-D better control, management and privacy. Most importantly, the coverage footprint of a commercial LTE network is far greater than unlicensed technologies like BLE (Bluetooth Low Energy) or Wi-Fi. The larger and more robust LTE coverage area also allows for higher network availability and reliability for the transport layer. Co-existing with minimal impact to existing mobile networks is critical to ensure a robust and pervasive implementation of LTE-D.

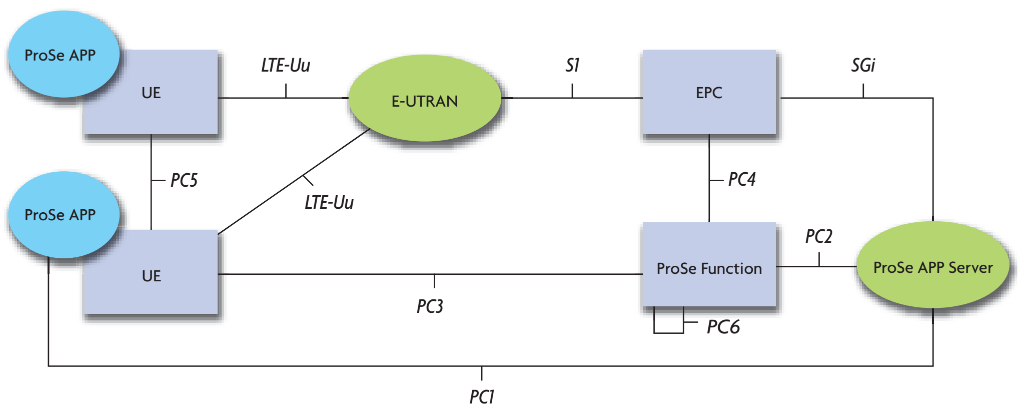
2 Use of LTE-U is not considered yet

3GPP Release 12 LTE-D introduces two new network elements, the ProSe Function and the ProSe App Server, into the LTE Evolved Packet Core (EPC).

LTE-D introduces two new network elements, the ProSe Function and the ProSe App Server,[3] into the LTE Evolved Packet System (EPS). These new network elements have three main roles for enabling devices to use LTE-D[4] which include:

1. Direct provisioning
2. Discovery name management
3. EPC discovery

Figure 1: LTE-D Network Interfaces and Components



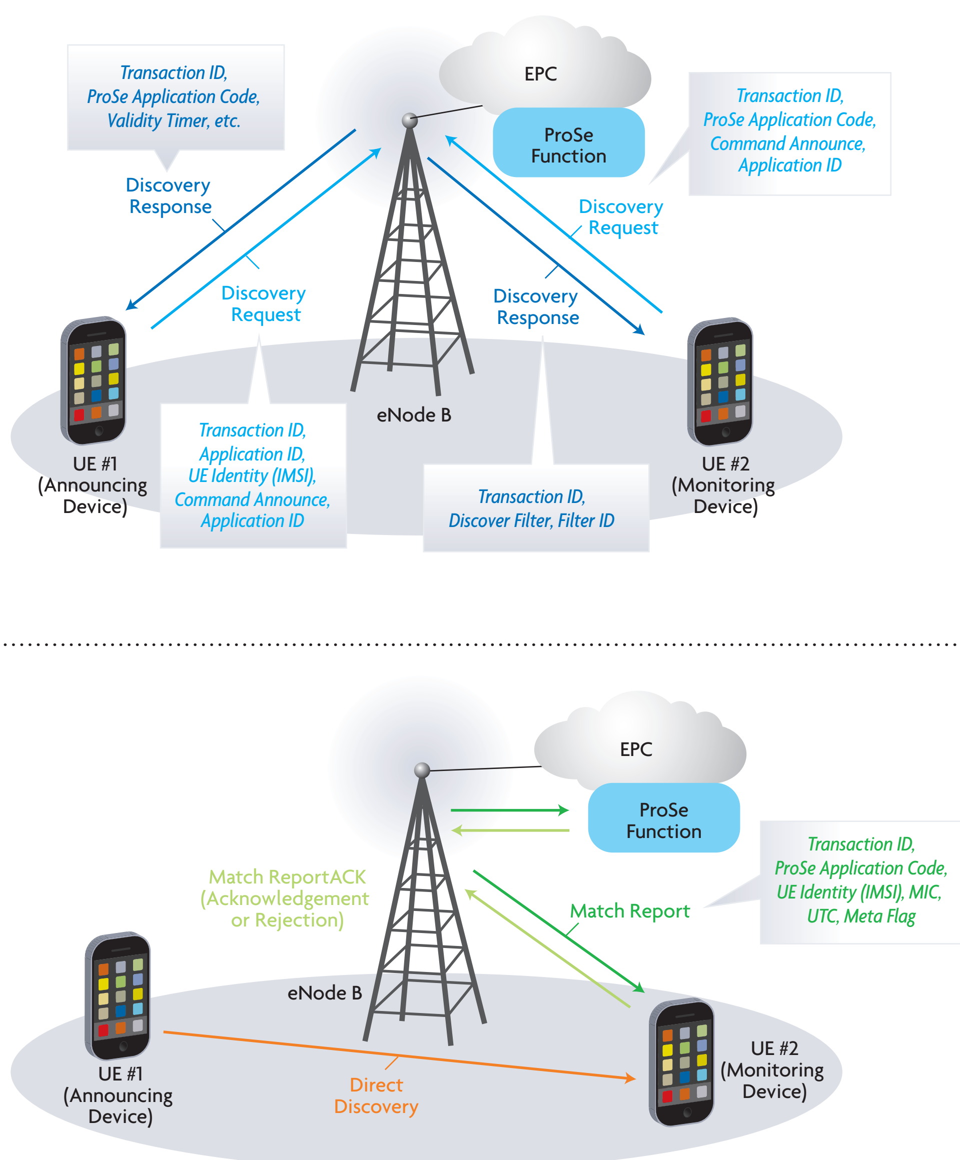
Source: 3GPP recreated by SRG

3 3GPP TS 23.303 - ProSe services Stage 2 document

4 http://cdn.rohde-schwarz.com/pws/dl_downloads/dl_application/application_notes/1ma252/1MA252_WP_LTE_Rel12_1E.pdf

In order for a non-public safety LTE-D device to be able to use Direct Discovery it must be authorized by the network to do so. The ProSe Function is the network node that processes the device service authorization and the ProSe Direct Service Management Object (MO) that is sent out by the device. This MO can take shape in two major forms as either an Announcing Policy or Monitoring Policy. These policies can help determine a variety of things such as whether the device is allowed to announce itself or be restricted from monitoring. Once the Discovery Request and Response transactions are completed, the devices or UEs use the direct PC5 interface to send out the Discovery Message – this is where the direct proximity aspect really comes into play. The LTE-D devices can now send out specific ProSe Application Codes.

Figure 2. LTE-D Direct Discovery Response



Source: Rohde & Schwarz (recreated by SRG)

The real elegance in this whole call flow is that the devices do not reveal the identity of the user, thus improving privacy while the entire process is autonomous to the end users so that they can always know what is pertinent to them without direct intervention or app interruption.

Expressions are broadcast to provide LTE-D users with various types of information or other similar proximal services.

The different roles that the ProSe Function performs ensure that application identifiers (App ID) and ProSe application codes (ProSe App Code) are mapped and allocated properly to each other. The App ID is also referred to as the "Expressions" that are transmitted from the beacon or the LTE-D device. These Expressions are broadcast to provide LTE-D users with various types of information, including social networking interests, offers for coffee, or other similar proximal services. With 3GPP Release 12, the number of bits for the Expression ID is increasing to a staggering 184 bits with up to 23 bits reserved for things like the PLMN ID.

LTE-D introduces two new SIB messages in SIB 18 & 19.

LTE-D also uses two new System Information Blocks (SIBs) that are transmitted over the LTE Radio Access Network (RAN). Specifically, 3GPP created SIB18 and SIB19 to support direct communication and direct discovery functions for LTE-D enabled devices. Interestingly enough, the PC-5 interface for LTE-D discovery and connectivity is now referred to as "sidelink" and is used in referencing the various physical and logical air interface channels.

LTE-D uses the same security architecture that LTE uses to provide USIM and authentication for network, user, and application domain security. In addition to this feature, LTE-D, as defined in 3GPP TS 33.303, has some very unique functions to ensure the privacy and security of users and their devices. There are multiple independent security procedures that exist for LTE-D direct discovery of another LTE-D device while in network coverage. Examples include

- **Service Authorization** – the home network can authorize a user to do direct discovery or disable it
- **Discovery Request** – the device obtains the configuration information for what Expression IDs to use
- **Discovery Procedure** – similar to an Expression ID checksum between sending and receiving device
- **Match Reporting** – checking the received expressions from an LTE-D device against the Network

3GPP has designed LTE-D with key security features.

The overall changes to the RAN architecture are relatively minor and are viewed as a "roadmap item" that have been well defined by 3GPP. The integration of the ProSe Function and ProSe App Server are relatively easy functions to integrate into a carrier's application server network and carriers are also looking to commercially deploy LTE-D as Virtual Network Functions (VNFs) within a NFV/SDN based network. However, the ProSe App Server will likely be deployed and managed outside of the carrier network. What this means to a network operator is that integration should be quick and costs minimized for integrating a new proximity technology.

LTE-D Device Integration

Since LTE-D is part of the 3GPP standards, it will be embedded into the RF and baseband chipsets, which will mean that every application can access the LTE-D functionality in devices with LTE-D enabled chipsets. In the move to commercial deployment, the ProSe[5] App will be accessed via the APIs in the device OS which will allow access to the underlying LTE-D functionality. This tight vertical integration of LTE-D into the smartphone allows application developers the ability to access and implement common and customized LTE-D functions in a horizontal fashion – giving app developers a greater degree of freedom to integrate their software with LTE-D functionality.

The LTE-D API will create a single touch point for end users, application developers and the network to access the LTE-D functionality. This feature is an important distinction. The access to LTE-D functionality can be done via the same mechanism from the network operator, application developer and end-user – this is what is often referred to as a "frictionless" interface. Multiple applications can access proximity information (as opposed to a single Bluetooth app) and give the end user a better and easier experience. Much of this is done by implementing a common expression database (which we'll discuss later in this paper).

To help promulgate LTE-D, Qualcomm created a portal specifically for early developers to get access to the trial LTE-D SDK and it is being actively used by several companies.

To help promulgate LTE-D, Qualcomm created a portal specifically for early developers to get access to the LTE-D SDK and it is being actively used by several companies.[6] Trial devices from Qualcomm and OnePlus have also been made available to early trials and testing. In our interviews with some of the early developers they all indicate they have had great success implementing the SDK, integrating it into their applications and using the trial devices.

The Competition – Legacy Proximity Services Technology

Society is moving in general to a personal, highly integrated, and localized way of communicating and doing business. The marriage of location awareness and mobile connectivity has been around for quite some time. Initially, Location Based Services (LBS) used the location provided by the internal GPS and other mechanisms like cell signals (e.g. Time Difference of Arrival – TDOA, called A-GPS) to geo-locate a user. With GPS and cell signals available on every mobile device, the adaptation of LBS services was relatively easy for application vendors. However, this is where things start to fall apart when you look closely at how LBS is being used for proximal services. Application developers initially had to create their own specific applications to access the LBS data and meticulously create geo-fences to correlate the proximity of the device to the store – adequate outdoors, nearly unusable indoors.

Although GPS is the prevailing location technology, it doesn't work indoors, it causes significant battery drainage when in use, and it has privacy issues.

As a result, each application used their own implementation and created silo's that were not easily interoperable with each other. Additionally, tracking continuously with GPS is necessary to get any usable updates on a person or device. This requirement opens up two very distinct issues – battery life and privacy. Anyone who has used an application that utilizes GPS on their smartphone continuously has seen a significant battery drain – some devices allocate nearly 30% of their power budget to supplying power to the GPS. The slow, constant data rate of GPS does not allow the device to go into "sleep mode" while the app is regularly getting location data, and uses precious energy on the phone.

5 LTE-D is referred to in 3GPP as Proximity Services or ProSe

6 https://ltedirect.qualcomm.com/

The other issue is privacy of tracking user's devices and giving that information to application developers or advertisers when the end user may not want that data shared. A Pew Research Poll[7] done a few years ago found that 30% of smartphone owners turned off the location tracking on their phoned due to fears of who had access to that information and that number surprisingly jumped to 44% in the 18-24 age demographic. As long as there is data, there will be someone who wants to get to it via a data breach. Companies like mSpy have developed popular phone tracking software that families can use to know where their children are. Recently though the system was maliciously hacked[8] and sensitive data was put on the internet. Having your discrete mobile device location details put out on internet is not something anyone wants to have happen so a better solution is necessary to combat this problem.

The second generation of proximal location uses beacons to address some of the deficiencies with A-GPS/GPS-based solutions. BLE or Bluetooth Smart has been around for a couple of years but it really became widely accepted after Apple announced iBeacon in 2013 at the WWDC. The BLE PXP (Proximity Profile) and iBeacon are synonymous with each other and iBeacon proximity companies (literally hundreds) have created a whole new ecosystem of devices and enabled new advertising markets to touch their customers.

iBeacons and Wi-Fi Aware allowed device-to-device communications and ushered in a new market for advertisers to reach their customers but it doesn't address the proximity issues solved by LTE-D.

This new market has created different types of devices for internet connectivity, health care, fitness, sensors and proximity sensing. BLE works well in most of these new market verticals for connecting to accessories like fitness sensors. While BLE for use in beacons has some distinct advantages over the GPS approach and overcomes some of the issues we discussed earlier, it doesn't fully address the proximity related issues as well as LTE-D. As its name states, BLE is a low energy device – the current draw is very low and battery life impact under nominal conditions is much better than traditional Bluetooth or Wi-Fi. Using a broadcast mode does allow for better privacy sensitivity and the standard does allow for AES128 encryption; however, many of the lower end devices do not implement this feature. Several manufacturers have been hacked and with simple hardware and free software you can track BLE devices in your proximity.[9]

BLE operates in unlicensed 2.4 GHz bands, making hardware readily available but it also operates in a very crowded space. Although the low power requirements are an advantage with respect to the battery life, the tradeoff is a greatly diminished range. The standard can support up to 50 meters, but in the real world the indoor performance of BLE and iBeacon is in the 10s of meters. An indoor effective range of 30 meters is considered far with characteristic near field performance in the 0.5-2 meter range.

BLE does not scale well with multiple beacons and affects phone battery life negatively.

The fundamental performance of BLE poses some additional problems. The periodicity of a BLE beacon transmitting can be in the tens of milliseconds on the low end or 10 seconds on the high end. These transmissions operate asynchronously of each other, with the default interval for iBeacons being 100 ms (10 times per second). Unlike LTE-D, BLE beacons are not synchronized, which causes problems with densely populated beacons (e.g. a shopping mall). The issue is that your device needs to wake up for each beacon that your phone is paired to or allowed to listen to and gather that data - which puts a significant strain on the operations of the BLE radio in the phones. In an 8 hour time period a typical device listening to one beacon may still have 97% of its battery life (when compared to baseline conditions) but when that jumps to 10 beacons under the same conditions it drops to 77% battery available – a 20% change due to beacons in the area.[10]

7 http://www.pewinternet.org/2012/09/05/main-findings-7/

8 http://www.bbc.com/news/technology-32826678

9 http://www.contextis.com/resources/blog/emergence-bluetooth-low-energy/

10 http://www.aislelabs.com/reports/ibeacon-battery-phones/

It should be noted that duty cycle (how many beacons you have in an area), battery and BLE implementation all play large roles in the performance and it does vary from device to device. So from a scaling perspective BLE may not cope well with a large amount of beacons.

However, BLE has a large and growing installed base of devices and stand-alone beacons. The beacon vendors have started adapting to the market and addressing issues. Newer beacons have programmable advertising intervals and power levels. Making adjustments to these can extend the stand-alone beacon battery life into several *years* of active use. This makes BLE based stand-alone beacons ideally suited for closer proximity, low interval and long life applications.

Wi-Fi Aware, unlike LTE-D, uses unlicensed spectrum and may suffer from significant sync, battery life and security issues.

This leaves us with the latest development from the Wi-Fi Alliance called Wi-Fi Aware that was announced at CES2015 – it is also known as Wi-Fi Neighbor Awareness Networking (NAN).[11] NAN was preceded by Wi-Fi Direct, a solution which is currently being used and which requires a peer-to-peer connection. Wi-Fi Direct required a two-step process for device and service discovery – this is an extremely painful experience for the end-user. The broadcast/inquest requests and unicast responses were and are unwieldy for real-time proximity services – thus the creation of NAN.

NAN has not yet been deployed but this implementation of Wi-Fi is meant to offer beacon-like services. The intent is to use the same Wi-Fi spectrum allocation and wake up the Wi-Fi radio to provide beacon heartbeats with a new protocol of published and subscribed messages that will be somehow synchronized. Much of the information for exchanging data will be handled at the application level – additionally security implementation is left to the application developer. Spoofing the NAN synchronization beacon frames is a known issue to the NAN design group and could open up denial of service attacks on NAN. The Wi-Fi Alliance, however, made the choice to not use the IEEE 802.11 MAC layer security for NAN – we'll see how that plays out in the future.

The synchronization of NAN is another concept with master and non-master devices providing and using timing off of each other – again it is unknown how well this approach will scale in large deployments. OS specific APIs for NAN that tie the applications to the NAN MAC are undefined at this point – making it impossible for vendors to effectively implement the technology. However, future trials of LTE-D and NAN both will utilize APIs where we will see how they really work and potentially complement each other. The intent though is that devices in proximity of each other set up a Wi-Fi Direct session with each other. If you've ever tried to use Wi-Fi Direct between disparate mobile devices, it is difficult if not impossible to connect devices due to different protocol stacks and OS implementations. Lastly, it is unclear how this beacon usage affects battery life or how battery life will be impacted in the mobile device. Given that Wi-Fi can use a lot of battery power, having a continuous beacon could be detrimental to battery life.

We should point out that NAN is a new proposal for Wi-Fi so all of our assumptions are based a limited information set. The Wi-Fi Alliance and their vendors have proven to be able to successfully address issues regarding security. It seems as though they are taking some of their cues from LTE-D with the manner in which they are addressing timing and scheduling proximity users. LTE-D should interoperate well with NAN and given the massive installed base of Wi-Fi devices, it should create enormous market opportunities. Our expectation is that the NAN proximity service will be similar in scale and experience to BLE beacons.

11 Wi-Fi Neighbor Awareness Networking Technical Specification 1.0

IrDA proximity sensors and ZigBee proximity detection are other proximity-based solutions that are on the market.

Infrared (IrDA) proximity sensors and ZigBee proximity detection are other proximity-based solutions that are on the market. IrDA is used on devices for near facial recognition to turn the device screen off when held to your head and extremely near field use. Some companies have used LED lighting and the IrDA cameras on phones to send data to phones but this is a niche and very limited use case and functionality.[12] ZigBee, although prevalent in home audio and security systems (and Arduino users), is something not found in typical smartphones. Its use for proximity services would require that smartphones include yet another radio technology, which could prove to be problematic. Widespread use of ZigBee for mobile device proximity services is highly unlikely to develop.

12 http://www.ledsmagazine.com/articles/2014/02/philips-lighting-demonstrates-led-based-indoor-location-detection-technology.html

New Business Opportunities from Carrier Grade Proximity Services

We spoke with a few companies that are starting to use and look at LTE-D integration into their software to see how LTE-D is truly helping usher in the next wave of personal communications.

LTE-D Market Enabling Companies

One company working with LTE-D is Compass.To.[13] This company's use case is to work on any platform and share stuff (i.e. anything you can think of) in proximity for social networking. It is designed to bring people together and enable connections based on interests and proximity. Initially, the company used Wi-Fi Direct and BLE combined with GPS and internet access to share stories, pictures and information. However, much like Foursquare and Swarm they didn't get the right person, at the right time and in the right location in an easy "frictionless" way. Using LTE-D the company is able to build a real-time proximity graph and use insight from that data to bring people and devices together.

Their application is intended to be a platform for applications like Facebook Nearby Friends, Instagram and other similar social networking applications to get and utilize proximal information for their customers. Retail usage scenarios range from being at a large flea market where Etsy sellers could discover Etsy buyers in their proximity to a band marketing manager who wants to notify fans listening to a band at SXSW that they are invited to join the band backstage because the fans have the band on their Spotify playlist. Large enterprise corporations are looking at this platform to market differently and more effectively. Compass.to also has been approached by several city councils and the UK Government on creating smarter cities. The application could, for example, alert mass transit users when busses or trains are delayed.

The Compass.to LTE-D-enabled application achieved close to a 100% improvement in battery life over the same GPS-enabled application and a maximum beacon detection range of 1.5 kilometers.

Compass.to observed an effective coverage area of 300 meters indoors on a consistent basis and over 500 meters outdoors for LTE-D discovery. This ability to reach out in proximity much further than other technologies has enabled the company to create a powerful proximity analytic engine that others can utilize for their own new business cases. Compass.to has also seen increased device battery life with their LTE-D based solution when compared to their existing GPS app. [14]

In the words of one early adopter, LTE-D Expression IDs are metadata for the real world, an interesting and appropriate interpretation for sure. Companies, like R/GA Labs, are looking at extreme crowd proximity services like New Year's Eve in New York's Times Square where they claim that up to 1,000,000+ people could be crammed into a 500 meter radius. LTE-D is the only technology that can potentially be capable to enable mass, seamless brand experiences in stadiums, concert halls and high traffic locations without having large infrastructure deployments.

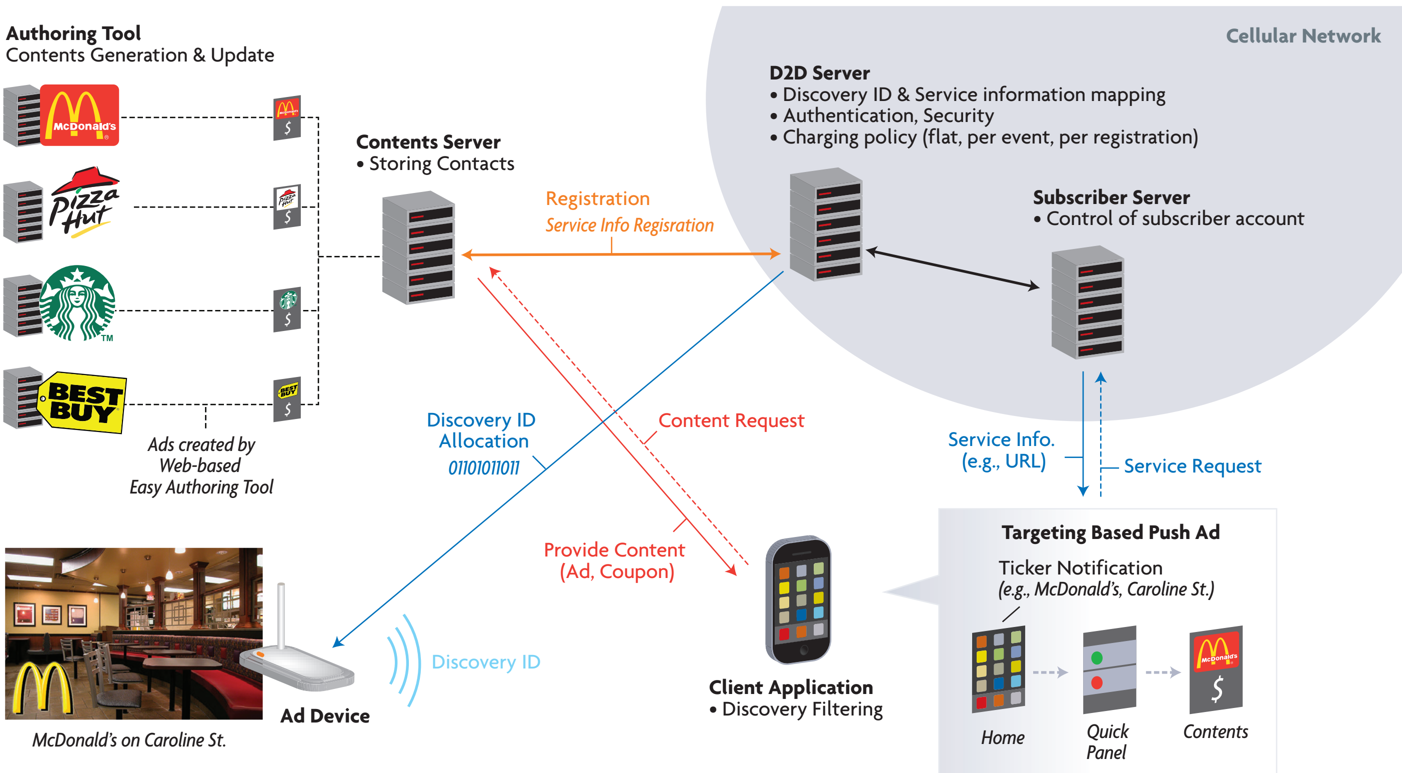
One of the more clever new business cases Company.to is working on is the inverted flash sale where you create artificial demand for a product. A consumer broadcasts its desired product (e.g. new jeans) and shopping mall retailers compete for your money when they see you broadcasting your desire for a specific product. The stores in the mall obtain information about the consumer in real-time and this information provides valuable insights that allow the vendor/retailer to prioritize sales and target the consumer's needs in real time when the consumer is in proximity to vendor or retailer. Brands are very interested in this strategy to get KPIs on everything from product sales to when to increase personnel staffing – only LTE-D can offer that.

13 http://www.compass.to/

14 SRG was not able to independently verify the performance claims by Compass.To

The NBA Sacramento Kings are creating what is most likely one of the more advanced basketball stadiums in the world where they want fans to have a fully interactive, immersive, and seamless experience. Using LTE-D commercial discovery, Expressions can allow their large crowd to interact via social media, and in the future it will allow for D2D interactive gaming and real time augmented reality. The Kings' owners believe in the 2 second advantage where a little bit of information obtained just a little bit beforehand, is more valuable than all the information six months later. The owners believe that LTE-D will afford them to implement this for their fans.

Figure 3. LTE-D Implementation



Source: Samsung (recreated by SRG)

Edge Routing with LTE-D

One of the companies that we've seen operate using this technology is M-87 (www.m-87.com) and they are using LTE-D proximity in a very unique way. M-87 is trying to take edge routing and network sharing to the next level. In the wireless packet network the core router provides connectivity within the network and edge routers typically sit at periphery of the network to route between disparate networks. The M.87 application scans the area automatically for other devices that have the M.87 application with LTE-D. It uses private expressions controlled by the network operator and end-user. Since these expressions are not publicly broadcast it provides an additional layer of security beyond the standard LTE security protocols and the Wi-Fi IPSEC and WPA2 protocols that M.87 uses in its application. The M-87 application is always seeking to maintain the best possible coverage and data rate for the user and it accomplishes this task by seeking a candidate or gateway device that has better RF conditions. The originating devices send all of their data intended for the internet APN out via Wi-Fi to the gateway device, which has better coverage on its cellular connection. The smart routing is designed to "cause no harm" to the user experience of the gateway device.

An example of this scenario would be when you are sitting in the back of a coffee shop with a poor LTE signal strength; however, someone else is sitting near the window where there is great coverage and available capacity. Voila – with this application you now have stellar coverage using LTE-D to find users with better coverage and connect to them using Wi-Fi Direct. When the person sitting near the window leaves the coffee shop, M.87 switches to a newer candidate gateway device that it has already detected with its LTE-D scanning process. During this scanning process, LTE-D detects other LTE-D devices and using the Expression IDs, the source device can determine from the responses which devices have the best coverage, have Wi-Fi enabled and are available gateway candidates. LTE-D has significantly longer and better discovery range than Wi-Fi and this disparity leads to a unique advantage for the M-87 edge routing implementation. The current M.87 implementation uses Wi-Fi for proximity detection and this process for locating and routing can take up to 30 seconds and has distance limitations due to operating in the unlicensed band. With LTE-D, the M.87 source device is able to "see beyond" what Wi-Fi can effectively do, allowing the device to detect many more candidates, determine best routes and create dynamic routing lists. In indoor locations where the RF environment is often changing very quickly, the M-87 application has already selected best candidates from its look into the future list before the RF conditions degrade. The app then creates dynamic, secure, virtual local area network (VLAN) connections to these new device gateways in a way that is seamless to both the gateway edge device and end user device.

In the trials that M.87 has performed the company is seeing about 500-600 meters (1600 – 1968 feet.) consistently for LTE-D beacon discovery, which can be tuned to match their requirements of 150-200 meters. With Wi-Fi, the M-87 application achieves a maximum distance of 60 meters with minimal performance. The Wi-Fi implementation of the application was also modified to have minimal impact on the battery while the company doesn't believe that BLE is a viable option given the use case for the application and the distances that it needs to support.

In addition to better performance of the radio environment, the integration of LTE-D allowed the application to locate candidate devices and route them accordingly in approximately two seconds – although commercial deployments will likely be 10 seconds for routing. With Wi-Fi, the comparable time for discovery and routing the traffic was approximately 30 seconds. Furthermore, having a signed application on Android and iOS gives them cross platform interoperability.

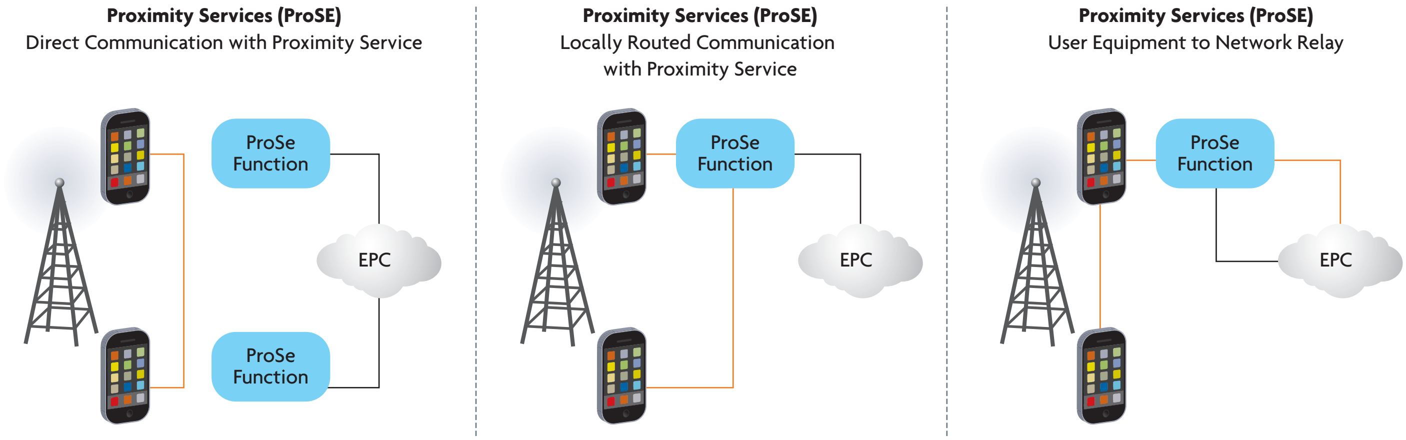
The use case for the M.87 application using LTE, LTE-D and Wi-Fi is intriguing and its implementation can create some very interesting business models. Although some people may find it strange to allow someone else to cruise the internet through their smartphones, in the Asia Pacific region countries and in the United Kingdom, the millennial generation is very open to sharing – especially if they get something out of it. Major carriers are looking into how to implement similar data sharing plans since they can create a better user experience for their customers and offload traffic from their congested networks. Authentication and billing are handled by the carrier network ePDG so that you are credited by allowing users on your connection or billed by using the Wi-Fi routing. To incentivize customers to use the service, users are enticed to share their connections and in return they get more data added to their plan and at faster speeds – the end user gets to control how much they utilize the application but increased participation yields higher data allowance. The business aspect speaks to offering a cost savings to the mobile network operator by freeing up congested networks since it allows for more users on the network – happier customers reduce churn.

When LTE-D eventually is deployed, companies, such as Facebook, are looking at how LTE-D will allow them to expose or create user experiences around friends or events nearby. Facebook is the poster child for implementing LTE-D as the company's user base is demanding Nearby Friends features that do not intrude on privacy barriers associated with constant location tracking which can also drain the battery with network pings. The ability to have a hyper-connected world where you have a device that senses your environment, learns your preferences, filters for those things that are relevant to you, and then goes and finds out what's around you that meet that criteria and interacts with you is no longer the future, it is the here and now with LTE-D.

New LTE-D Roadmap Features

The vision, scope and capabilities for LTE-D are growing with each release of 3GPP. The roadmap of features for Release 13 and beyond have significant feature enhancements for commercial and Public Safety use.

Figure 6. R13 LTE-D Enhancements



Source: 3GPP (recreated by SRG)

The term eProSe is now used in 3GPP Release 13 to refer to these new enhancements and the evolution of proximity-based services. Public Safety features for LTE-D include discovery for Public Safety use, network relays, device-to-device relays and LTE-D direct communications (one-to-one directly). There are even more enhanced security features for Public Safety and one-to-many ProSe functions that have been defined. All these new and enhanced security requirements have shown that 3GPP has taken a very serious step in ensuring securing and privacy for LTE-D.

For non-Public Safety use, restricted LTE-D discovery will be implemented for improved privacy. Enhancements to existing LTE-D services for non-Public Safety out of network coverage proximity use, and multi-carrier PLMN support are all under discussion. Additional use cases and features for LTE-D are also being considered for vehicle-to-vehicle communications as the demand and requirements by governments for intelligent highways increases.

Challenges with LTE-D Implementation

Proximity based services are not without significant challenges. When talking to one of the early developers using LTE-D they said that battery life and range are no longer limitations like previous technologies (e.g. BLE and Wi-Fi) and their challenge is understanding what is possible with LTE-D technology. Although not really a problem, the application developers are wanting to push the boundaries of technology to use it in ways we may have not mentioned. In order to do this it requires access to spectrum, devices and carriers.

More extended trials will help expose any areas for improvement but LTE-D does have some major hurdles to overcome.

Getting LTE-D into new smartphones from leading handset manufacturers is fundamental to its success. Gaining critical mass of devices enabled with LTE-D will for sure be a challenge as the technology should be available from low tier beacons and devices, to flagship smartphones. The deployment and widespread adoption of LTE-D in Android and iOS devices will be possible soon with 3GPP Release 12 standards completion and initial deployments in 2016. We believe that LTE-D market commercialization is poised to start ramping in late 2016 and early 2017.

Another challenge is that LTE-D devices will need to implement additional components in the RF front end as transmissions operate in the uplink band. For LTE TDD devices/bands this requirement isn't an issue but for FDD only devices it becomes a minor design challenge, which we believe OEMs will implement with relative ease.

Early developers question whether or not devices with LTE-D will perform similarly when compared with each other. One of the reasons for this concern is that there has been widespread consistency issues with iBeacon performance and application developers want to know that they will get consistent performance from device to device. Luckily, 3GPP RAN 5 has been working to finalize RF, Radio Resource Management (RRM), and protocol conformance test specifications for LTE-D. Their work has mostly been completed and test equipment vendors, GCF and PTCRB are working currently to implement new test cases to ensure nominal interoperability and performance (e.g., 3GPP TS 36.521-1, 36.101).

LTE-D needs multiple network operators to deploy LTE-D to ensure interoperable proximity and discovery between network operators and implement LTE-D as part of their spectrum strategy. Of the 44 RF bands defined by 3GPP only 10 bands currently have been specified to support LTE-D functionality (this can easily increase). 3GPP requires network operators to request LTE-D band support to implement the feature into the standards and that can be driven by consumer/enterprise demand – planning now has to be done in anticipation of LTE-D support. If a new band needs to be implemented, it can be a 9-12 month cycle to implement that into the OEM device eco-system.

To help frame the issue we need to understand that LTE-D operates currently on the uplink of licensed spectrum and each operator maintains unique spectrum allocations. To ensure regional or global LTE-D interoperability carriers will have to agree to either deploy LTE-D in a common roaming band, use a common band for discovery (i.e. Band 20), or potentially use a PPDR/Public Safety band (Band 14 and Band 28). This is an issue that could represent the biggest hurdle to the widespread adoption and success of LTE-D.

Lastly, the LTE-D "Expressions" that are used to identify discovery need to be managed on a global or regional basis. This requirement pertains to the LTE-D Expression database mapping of the 184 bit expressions that are used by LTE-D. This requirement isn't a difficult task but it is a necessary one to ensure interoperability and usability. Currently, there are not any organizations maintaining an official, public LTE-D Expression database. However, there are entities that could do this management. Examples include the GSMA, as well as regional standards bodies, such as ATIS, which could create, manage and allocate the LTE-D Expression Database and coordinate with other regional bodies and/or GSMA – similar to what is done for PLMN IDs. Another approach would be to utilize third-party companies that maintain beacon databases. These companies could manage the LTE-D Expression database and provide access to LTE-D developers and advertisers in perhaps a quicker and more user friendly fashion – think domain names from GoDaddy and HostGator from the internet world.