Cell Phone Tracking: Trends in Cell Site Precision
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In order to offer better service, cellular phone companies over the past 10 years have installed hundreds of thousands (by some counts millions) of new antennas to handle calls. Some of these cell sites cover very small areas, and the location information indicated by these sites can be as precise as that generated by GPS. As a result, during the course of an average day, the average cell phone user is increasingly likely to be connected at one time or another to one of these very small cell sites, often inside private spaces such as homes or offices. Industry projections indicate that this trend will continue.

Background

There are several ways to geo-locate a cell phone. One is GPS (Global Positioning System), which uses signals transmitted by a network of satellites maintained by the U.S. government. All cell phones sold in the U.S. have a GPS device that can receive these signals to determine the phone's location.[1] GPS has a location precision of about 10m. However, GPS only works outdoors and in good environmental conditions and often can be disabled by the user to reduce battery drain.

The location of a phone can also be estimated based on the network antenna to which the phone is connected. Each time a cell phone communicates with an antenna, the wireless carrier records the "cell site identifier." Carriers know the precise latitude and longitude of all or almost all of their antennas, so the cell site identifier can be translated into the GPS coordinates associated with that antenna. The size of the area served by an antenna determines the accuracy of the data in locating the phones connected to that antenna.

In addition, other technologies are used to generate location data. Some phones, for example, "listen" to surrounding wireless Internet signals (WiFi) and use commercial services that map these signals to locate the phone. Increasingly, phones use a combination of these methods to more quickly and accurately generate location information, which may be conveyed to the company whose operating system runs the phone, to a mapping service, or to other applications running on the phone. [2]

The Drivers of Cellular Network Development

In theory, a cell antenna can provide service to an area of up to 10 square miles and there are many cell towers in operation today that cover large areas. However, several factors have been driving carriers to create many more cells, including some serving very small

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[1] "100% of the new handsets sold since December 31, 2003 are GPS-capable." *See,* "E911 Compliance FAQs," Verizon Wireless, http://support.verizonwireless.com/faqs/Wireless Issues/faq_e911_compliance.html (last visited April 18, 2013).

[2] "Apple Acquires WiFiSLAM for its Indoor Location-Tracking Tech" (March 24, 2013) (noting that Google Maps has more than 10,000 floor plans for shopping centers and other buildings in 13 countries; the company uses a mix of Wi-Fi hotspot triangulation and cell tower-based location to let users plot their precise location inside these buildings).

areas. To begin with, there are over 320 million wireless subscribers in the U.S.[3] Each antenna has a fixed number of calls it can handle. In densely populated areas, too many people trying to make calls will saturate an antenna so no further calls will be possible. The rapid integration of data services into phones (text, email, Web browsing, apps, video) has further burdened networks with huge added volume.[4] In addition, obstacles such as terrain and buildings can greatly diminish the ability of a phone to communicate with a nearby antenna, in some cases resulting in "dead zones." Urban environments are particularly challenging as customers are constantly moving between and inside buildings, which block signals.

The Solution: Smaller Cells

The cellular phone industry is intensely competitive. To provide better service to more customers in a given area, wireless providers have been augmenting their networks with many smaller cells, each with its own antenna. The areas served by these new cells are much smaller than the old ones, resulting in a smaller geographic area (and increased location precision). These small cells are called "microcells," "picocells" and "femtocells." The exact specifications for each term vary, but according to one source, microcells, picocells and femtocells provide service to areas of 200m-2km, 4m-200m and 10m, respectively.[5] It is widely agreed that the term "femtocell" refers to a cell covering an area the size of a house or office.[6]

The trend began several years ago when carriers began selling femtocells to their residential customers, with one carrier advertising the service as "getting a million-dollar cell site in your home."[7] In 2010, Sprint announced that it would give away femtocells for free to customers with weak 3G coverage inside their homes.[8] The next phase was the deployment of

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[3] "Background on CTIA's Semi-Annual Wireless Industry Survey," CTIA (2012) http://files.ctia.org/pdf/CTIA_Survey_MY_2012_Graphics-_final.pdf.

[4] One study expects mobile data traffic to pass 90,000 petabytes by 2017, "roughly equivalent to nearly 42 quadrillion tweets or around 7 billion Blu-ray movies." International Business Times (April 15, 2013) http://www.ibtimes.com/press-release/20130415/how-wi-fi-small-cell-offloading-solutions-will-ease-network-congestion

[5] Dimitris Mavrakis, "Do we really need femtocells?" VisionMobile Blog (Dec. 1, 2007) http://www.visionmobile.com/blog/2007/12/do-we-really-need-femto-cells/.

[6] For more on femtocells, see generally: http://www.fcc.gov/help/public-safety-tech-topic-23-femtocells and http://opensignal.com/reports/femtocells.php.

[7] Verizon Press Release, "Verizon Wireless "Network Extender" Enhances In-Home Call Capabilities: 'Like Getting A Million-Dollar Cell Site In Your Home For $249.99'" Jan. 26, 2009, http://news.vzw.com/news/2009/01/pr2009-01-26c.html. (The price for the Verizon femtocell has fallen substantially.) "To shift the burden on its network to the Internet, AT&T is selling microcells to its cellphone customers, which they install inside their homes." Damon Darlin, "Cellphone Carriers Are Turning to Wi-Fi, Too," New York Times, Sept. 11, 2010 http://www.nytimes.com/2010/09/12/business/12every.html?src=busln. See also Roger Cheng, "A Cell Tower of Your Very Own; Major Carriers Sell a Personal Device that Improves Signal," Wall Street Journal (July 8, 2010) http://online.wsj.com/article/SB10001424052748703636404575353153350315146.html?mod=googlenews_wsj.

[8] Eric Savitz, "Sprint Giving Femtocells To Some Customers; Will VZ, T Follow?" Barron's, Sept 15, 2010, http://blogs.barrons.com/techtraderdaily/2010/09/15/sprint-giving-femtocells-to-some-customers-will-vz-t-follow/

femtocells in office buildings.[9] Since then, Sprint has gone perhaps the farthest in deploying femtocells: As of last October, it had deployed over 1 million femtocells in homes, businesses and public places.[10]

A key point for privacy: Femtocells are equipped with GPS receivers so they can report their location to the carrier when being set up (this serves a spectrum licensing purpose and is critical in order to trace the origin of an emergency call).[11]

Across all carrier networks, there are now far more femtocells than traditional cells (with each femtocell serving only a handful of customers at a time).[12] According to one industry group, the number of small cells is projected to increase by a factor of eight by 2017.[13]

The latest trend is in the deployment of "metro cells," small cells installed by operators in public or open access areas, such as malls and convention centers, and in office buildings and hotels. Metro cells are "especially effective for indoor locations like office buildings and shopping malls, where a macro-only network struggles to penetrate" (and where GPS may be totally unavailable).[14]

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[9] Nancy Gohring, "Femtocells make their way into the office," Computerworld (March 7, 2011) http://www.computerworld.com/s/article/355071/Femtocells_Make_Way_Into_Enterprises

[10] Sue Marek, "Sprint's femtocell tally tops 1M" (Oct. 24, 2012) http://www.fiercewireless.com/story/sprints-femtocell-tally-tops-1m/2012-10-24?utm_source=rss&utm_medium=rss. See also "Sprint planning extensive small cell deployment over the next three years to aid LTE rollout" (May 10, 2012) http://www.theverge.com/2012/5/10/3011498/sprint-small-cell-deployment-lte-rollout.

[11] Berthold Horn, "More femtocells than cell towers?" http://opensignal.com/reports/femtocells.php. See also "Femtocell UMA Access Point Carrier Implementation Detail" http://c.ymcdn.com/sites/www.nena.org/resource/collection/1F053CE7-3DCD-4DD4-9939-58F86BA03EF7/NENA_03-509-v1_Femtocell_UMA_Appendix.pdf and https://softhandover.wordpress.com/2010/08/09/femtocells-with-gps/.

[12] "Press Release: Small Cells Outnumber Traditional Mobile Base Stations", Small Cell Forum (October 31, 2012), available at: http://www.smallcellforum.org/newsstory-small-cells-outnumber-traditional-mobile-base-stations. One study found, for example, that Verizon Wireless had roughly 7000 antennas on traditional cell phone base stations in Eastern New England, but 17,000 femtocells. Berthold Horn, "More femtocells than cell towers?" http://opensignal.com/reports/femtocells.php.

[13] "Press Release: Public access small cell market to hit US$16 billion in 2016", Small Cell Forum (February 26, 2012), available at: http://www.smallcellforum.org/newsstory-public-access-small-cell-market-to-hit-us-16-billion-in-2016; "iGR Studies Forecast the U.S. Total Addressable Market for 4G LTE Metrocells Set to Grow at a 240% CAGR Over the Next 5 Years, While U.S. Residential Femtocells Could Grow at a CAGR of 86%: Small Cells, Including Both Metrocells and Femtocells, Will Be Part of the Het-Net Solution to Meet the Rising Demand for Mobile Data" http://www.marketwatch.com/story/igr-studies-forecast-the-us-total-addressable-market-for-4g-lte-metrocells-set-to-grow-at-a-240-cagr-over-the-next-5-years-while-us-residential-femtocells-could-grow-at-a-cagr-of-86-2012-12-11.

[14] See "Metro Cells, The Bigger Picture" "Metrocells 101: what are they, where would you use them and how do you set them up," Alcael-Lucent (Dec. 4, 2012) http://www2.alcatel-lucent.com/blogs/corporate/2012/12/metrocells-101-what-are-they-where-would-you-use-them-and-how-do-you-set-them-up/.

Femtocells have another advantage: they typically send cell data over a commercial broadband Internet connection, allowing carriers to "offload" traffic from the traditional telephone infrastructure to the Internet. In a data-intensive environment, the desire to offload traffic onto the Internet will be a major driver for deployment of small cells. One industry reports concludes: "Mobile operators will increasingly turn to small cells to address capacity and coverage issues in 2013, with volume shipments increasing significantly in 2014."[15]

In sum, the cellular network today combines traditional cells with many different configurations of small cells (and WiFi network elements) that together provide a mosaic of coverage, and the economics of the intensively competitive industry will continue to drive the deployment of various small cells.

Implications for Privacy

While it is still the case in rural areas that location derived from cell phone antennas is not comparable to GPS (10 meters), in a growing number of cases, especially in urban areas, location based on antenna location will approach GPS-level precision. If a cell phone is associated with a cell site identifier for one of these smaller antennas, the location of the phone is known to be within the specific geographical range of that antenna. Notably, femtocells and other small cells are used to provide connectivity to floors of buildings, individual offices and homes, all locations within traditional Fourth Amendment protections.

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[15] How Wi-Fi and Small Cell Offloading Solutions Will Ease the Network Congestion," International Business Times (April 15, 2013) http://www.ibtimes.com/press-release/20130415/how-wi-fi-small-cell-offloading-solutions-will-ease-network-congestion