Alcatel·Lucent

Exploring Traffic Geo-Location as a Key Strategy to Off-load Macro Networks with Small Cells Solutions

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Abstract

For mobile service providers (MSPs) all over the world, network congestion is a critical issue that will only become more important and more challenging as mobile traffic continues to grow unabated. The more service providers understand what services and users are driving network congestion and where and when it occurs, the better prepared they will be to deploy innovative and practical solutions. Traffic geo-location is one of the most promising and talked-about areas of exploration, giving MSPs the opportunity to optimize and maximize their investments. It is particularly useful when deploying small cells solutions to off-load network capacity.

MSPs face myriad complex issues when demystifying their networks: scarce spectrum, difficult site acquisition, capital expenditure (CAPEX) limitations and exploding demand for data services, among others. The challenge is not just to off-load network traffic, but to do so in the most cost-effective manner possible so that services can be delivered profitably. Traffic Geo-Location Services can be an invaluable solution in helping operators determine the optimal locations for small cells deployment — specifically those locations that offer the best off-load from the macro

network and therefore the maximize return on investment. In this paper we explore the benefits of Traffic Geo-Location Services, as well as the technical and business issues that MSPs need to consider in order to deploy effective and innovative off-loading solutions.

1. Market Overview

The growth in mobile data traffic is an unstoppable force. By 2015, the total mobile data traffic generated by smartphones, feature phones and tablets is expected to exceed a staggering 14,000 petabytes per year, according to a report by Juniper Research. Alcatel-Lucent estimates that the number of smartphone connections will grow from 500 million in 2010 to 2.5 billion by 2015. According to a survey by traffic management vendor Allot Communications, overall mobile data traffic grew by 77 percent in the first half of 2011 alone, following growth of 73 percent in the second half of 2010, driven largely by a sharp increase in video streaming usage.

For mobile service providers (MSPs), the challenge of uncontrollable mobile data growth is being addressed by network off-loading solutions using technologies such as small cells (femtocells and metro cells) and Wi-Fi. According to Juniper Research, the amount of data traffic that is being off-loaded from operator networks to other complementary networks will increase to 63.2 percent by the end of 2015, compared with 43.1 percent in 2010. By 2015, the annual mobile data traffic off-loaded from operators' networks via Wi-Fi and small cells will reach 9,000 petabytes, or, as noted in one prominent trade journal, the equivalent of 11 billion movie downloads.

For MSPs, however, **the challenge is not merely to off-load data traffic, but to do so in the most effective manner possible**. From a business perspective, MSPs are facing unprecedented pressure to keep up with growing data demand while also creating new business models to successfully translate that growth into corresponding growth in revenue and profits. At the same time, they are facing the technical challenges and increased costs of adding network capacity at an unprecedented rate.

In addition to the obvious focus on profitability and the creation of profitable revenue streams, there are several other critical reasons why MSPs must employ a strategy that maximizes and optimizes their investment in network off-loading, including:

- **Spectrum Limitations:** As MSPs know all too well, spectrum is a limited and valuable resource that must be managed carefully and efficiently and is subject to regulatory, availability and other restrictions challenges. The benefits, of course, are in security, quality of service (QoS) and the ability to support the same services as the macro network. In addition, small cells solutions provide more flexibility in spectrum reuse, therefore increasing capacity.
- **CAPEX Limitations**: MSPs don't have unlimited budgets for capital expenditures and therefore must invest wisely in developing next-generation solutions. To help MSPs understand what a typical metro cell deployment might look like, Alcatel-Lucent Bell Labs Business Modeling and Wireless Network Design teams conducted a five-year case study that compared the total cost of ownership (TCO) of metro cells with a traditional macro expansion solution. The solution supported the rollout of 1,700 metro cells, which provided a full network off-load for the entire city in which the case study took place. The study results indicated that the TCO for the deployment of metro cells was 45 percent of the cost of the macro cell upgrade, giving metro cells a 55 percent cost advantage.

However, Juniper also pinpoints a critical stumbling block: **"The challenges have always been how to execute the deployment of microcells and to find all of the places to deploy the necessary access points."**

Incorporating a Traffic Geo-Location Service allows MSPs to create an optimized environment for their network off-loading solutions that delivers the additional bandwidth required for their customers and maximizes their CAPEX investment. With an effective solution for traffic geo-location, MSPs can create huge volumes of raw data on all of their coverage areas — particularly those high-density hot spots — and then process that data for a better and more efficient design of their network. The ability to generate high volumes of data creates the foundation for efficient network design and implementation. Once the data is captured, it can then be processed with Bell Labs' proprietary algorithms to create traffic density maps based on actual traffic patterns and to indicate where to deploy small cells.

2. Technical Solutions for Geo-Location

There is plenty of statistical and anecdotal evidence to show that mobile data hot spots are small, well-contained geographical areas that are typically the source of large volumes of traffic. Research from Alcatel-Lucent has indicated that 2 to 3 percent of users generate 40 to 50 percent of mobile data traffic and that 60 to 70 percent of mobile data is generated by nomadic users indoors.

By using traffic geo-location as a go-to technology, MSPs can maximize their investment in small cells by successfully matching traffic hot spots with small cell coverage. The advantages are:

- Accurate geo-location information, ideally for all active subscribers in a given cell site coverage area or, alternatively, in a large enough sample of active subscribers to provide confidence in the identification of the hot spots.
- Accurate subscriber usage information for voice calls, packet data, streaming video and other services offered by the MSP.
- Improved overall coverage in the area by off-loading traffic from the macro cell, increasing capacity within the given spectrum.
- The ability to correlate location and usage to produce a "heat map" showing where hot spots are located and their intensity.

Accurately determining the location of a wireless subscriber is difficult because of the nature of wireless networks. For one, mobile users are not tethered to a single location, which means if a subscriber is located once, there is no assurance that his location will not change at a later time. Likewise, the varying conditions of wireless networks (signal strength, interference, radio access bearer, etc.) mean that network information is not static; a solution that works at one moment in time may not work later, when network conditions change.

There are generally three main techniques for estimating the location of a wireless user. Other techniques are possible but are typically less applicable and require much more complicated analysis and computation. Because we are interested in performing geo-location on all wireless users in the area of study — typically a cell site — these more complicated techniques are not as useful as those described here.

Cell-ID Method: The cell-ID method provides the identification of the serving cell (sometimes referred to as the serving sector) for an active wireless subscriber as an estimate of their location. The cell ID can be obtained from the signaling information used to set up or maintain a wireless call. The technique has limited accuracy, since it can only identify the location of a user to the area covered by the cell, which can be quite large. For this reason, it is not generally useful for the Traffic Geo-Location Services investigated in this paper.

Assisted GPS (A-GPS): This method requires that terminals be equipped with GPS. It makes use of the GPS capabilities of the user device and the availability of a GPS satellite network to provide highly accurate location information for an individual user. A GPS is used for E911 emergency services in the United States, where it has an accuracy requirement of 67 percent of the time for distances of 50 meters and 95 percent of the time for distances of 150 meters. A-GPS is a refinement of GPS where the network stores information that can be provided to the user equipment to help speed up the process of acquiring the required number of GPS satellites to allow for GPS geo-location. Even with network assistance, A-GPS can be somewhat slow. Two other concerns make A-GPS a less-than-ideal candidate for the purposes of a Traffic Geo-Location Service: (1) not all user equipment is equipped with GPS capabilities and (2) GPS features tend to use a significant amount of power, which means wireless subscribers will sometimes turn off the GPS functions on their GPS-enabled devices. Also, GPS requires line-of-sight access to multiple GPS satellites, which means the technology does not work well indoors. All of these reasons result in A-GPS being not particularly well suited for the needs of the Traffic Geo-Location Services being investigated here.

Triangulation: Triangulation is a mathematical technique by which the location of a point in a three-dimensional environment can be determined by knowing the distance between that point and at least three other fixed points on the network. The more accurate the information about these distances, the more accurately the calculated position of the point of interest can be obtained. Location estimates of lesser accuracy can be obtained by knowing the distance to two or even one other point in the network. Data can come from either Call Traces or probes.

In wireless networks, obtaining distances from the point of interest — the wireless user — to the other fixed points — the base station — is generally accomplished by measuring the time it takes to transmit information from the user to the other fixed points and using that time to estimate the distance based on the propagated speed of the information. Adjustments can be made to the estimate of the distance by factoring in known delays, if any, in the propagation. In wireless networks in urban environments, the triangulation method can provide estimated accuracies of 150 meters most of the time.

In cases where there are fewer than three cells in the active set, the accuracy of the geo-location based on triangulation is reduced. For cases where there is only one cell in the active set, the distance estimate provides an arc centered at the macro cell where the user equipment is located. Typically, some assumptions are used to determine where on the cell arc the user equipment is positioned. In instances where there are two cells in an active set, two sets of distances can be computed and the location of the user equipment on the arc could be determined by calculation. In these cases, tool vendors can provide solutions that improve the accuracy of geo-location estimates.

As MSPs go through these processes, there will be specific considerations for each of the potential technical scenarios for their Traffic Geo-Location Services. For instance, if MSPs are considering an A-GPS solution, they have to make sure they are targeting a market segment that will be using GPS and where the end users will likely have the GPS feature turned on. This would suggest hot spots in which smartphones and feature phones are predominantly used, as opposed to, say, laptop computers.

With systems based on triangulation methods, the MSP has to understand its own capabilities and the impact the solution might have on the radio access network (RAN). Solutions from some vendors have the capability of tracing all calls, while others can support only some calls. In addition, Call Trace puts an additional load on the RAN. With probes, every call can be recorded, with no additional load requirements on the RAN. Probes can also operate 24 hours a day, seven days a week, although signaling delays affect the accuracy. Another technical consideration is the sampling rate at the chipset level. Different types of equipment from different vendors use different sampling rates on the chip to perform call-records measurements, resulting in varying accuracies. Accuracy of the data is the same regardless of the solution, whether probes or Call Trace.

As MSPs and Alcatel-Lucent continue to explore alternative ways to maximize the performance and capacity of mobile networks, it is entirely possible that innovative drive test solutions will emerge — for example, using robots or helicopters to give a 3-D view in complex environments. While solutions such as these are not yet available, the possibilities for future innovation have often been driven by industry needs and the pioneering work at Alcatel-Lucent Bell Labs.

3. Technical Considerations

When it comes to deciding which of these potential solutions makes sense, there are specific issues that need to be evaluated. From a big-picture standpoint, important considerations and steps for the service provider are:

- Understanding and articulating objectives — technical and business — starting with the current status of the network and an estimate and plan for the evolution of the network.
- Understanding and forecasting the potential impact of user devices and user expectations, including new features that may become available on devices and new data services that will drive incremental bandwidth requirements.
- Exploring possible off-loading solutions.
- Determining which cells/sectors are likely to hit capacity bottlenecks of macro cells, based on various profiles.
- Generating traffic-density maps for assessment of hot spots.
- Determining the optimum macro off-load strategy, depending on accurate information about current data along with forecasted information about traffic evolution.
- Simulating small cells deployment in the most traffic-dense areas, looking at backhaul constraints, end-to-end QoS and quality of experience (QoE) requirements, capacity requirements, spectrum challenges, etc.
- Running associated business cases.

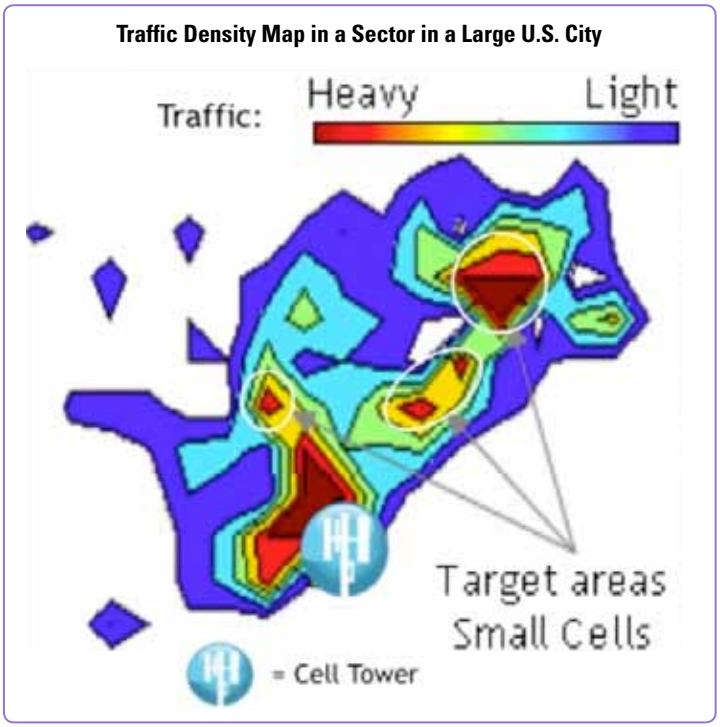
4. Business Considerations

Regardless of the specific traffic geo-location methodology used to generate the raw data from the network, the overall goal of Traffic Geo-Location Services is to make the deployment of the metro cell solution as effective as possible in terms of maximizing network resources, expanding capacity, delivering QoS and making the user experience pleasant, accurate, scalable and reliable. In evaluating TOC, key business questions to ask include:

- In which part of the network does it make sense to introduce small cells?
- What types of small cells should be considered?

In a real-world example, which is the result of an exercise done by Alcatel-Lucent for a Code Division Multiple Access (CDMA) network in the downtown area of a major city, it can work as follows. In CDMA, there is significant per-call measurement data. For every single call or data session, the network generates key statistics, including number of call attempts, SINR, uplink and downlink data volume and round-trip delay measurements from serving and neighboring cells. In the example cited, high volumes of this data are processed with Bell Labs proprietary algorithms to create a traffic density map, such as the one in the diagram below. In this plot, the darker the color, the heavier the traffic is. The key is that the traffic geo-location system can generate this raw data, and then the data can be post-processed effectively for a better and more efficient network design. The Bell Labs advanced algorithms are indeed able to compute the "top-N" metro cell locations driving the best off-load and thereby maximizing return on investment. Simulations show that with this method, only a small number of small cells are required to reach a significant off-load.

Traffic Density Map in a Sector in a Large U.S. City



Today, small cells provide typical coverage range from less than 100 meters in dense urban locations to several hundred meters in rural environments. Unlike home and enterprise cells, metro cells are owned and managed by the MSP and are typically used in public or open access areas to augment the capacity or coverage of the larger metro networks. A significant advantage of utilizing metro cells is that the MSP has far more options in site acquisition for cell location, which is often a limiting factor in network expansion and flexibility. The small form factors of the metro cells allow for new kinds of sites for cell location, such as building facades, lampposts, traffic lights and billboards.

5. Deploying Innovative Solutions

The opportunity to effectively utilize some type of Traffic Geo-Location Service is clearly a compelling one for MSPs seeking to deploy off-loading solutions. Successful deployment will help to address the significant challenges involved in network growth and expansion, giving providers a more potent and efficient method of delivering key services to a growing constituency of customers who are demanding more and more bandwidth. From the customers' standpoint, the benefits will be in the ability to maintain a high quality of experience while taking advantage of exciting new services that provide more flexibility, more enjoyment, greater productivity and ever-growing opportunities to explore the expanding wonders of this digital age.

As MSPs explore the opportunities to deploy off-loading solutions as well as all of their changing infrastructure requirements, Alcatel-Lucent is there as a knowledgeable, experienced and fully committed partner. Traffic Geo-Location Services is one piece of Alcatel-Lucent's broad portfolio of products, services and consulting solutions available to MSPs worldwide. It will help MSPs address the challenges of network growth and capacity expansion and enable new generations of products, such as lightRadio™, a system announced in early 2011 by Alcatel-Lucent that streamlines and radically simplifies mobile networks.

The lightRadio system represents a new architecture where the base station, typically located at the base of each cell site tower, is broken into its component elements and then distributed into both the antenna and throughout a cloud-like network. The system is expected to give MSPs the capability to potentially double the capacity on their macro networks while reducing the cost per bit by 50 percent compared with conventional 3G approaches. Savings accrue to MSPs through reduced power consumption of up to 50 percent, along with reductions in site rental, permitting and maintenance costs. By pairing a Small Cell Geo-Location Service with lightRadio, MSPs can create breakthrough solutions to address their network expansion challenges.

6. Conclusion

In order to profitably deliver the types of mobile data services customers are demanding, there is no doubt that MSPs must come up with innovative — yet practical — ways to significantly expand the capacity of their networks. The existing RAN must be expanded through the use of alternative solutions, such as metro cells, that address the challenges of limited spectrum, limited CAPEX availability, difficult site acquisition and the ever-present challenge of delivering a high QoE for the user. By exploring next-generation solutions, MSPs have the opportunity to position themselves to not only deliver the services that customers are demanding, but to also be leaders in creating the next generation of services that will continue to drive growing demand

for mobile data applications. By exploring the opportunities available to them in deploying metro cells and maximizing their metro cell deployments through traffic geo-location, MSPs have the opportunity to invest wisely in their future and in the future of their customers.

Acronyms

• A-GPS	Assisted GPS
• API	Application Programming Interface
• CAPEX	Capital Expenditures
• GPS	Global Positioning System
• HSUPA/HSDPA	High Speed Uplink Packet Access/High Speed Downlink Packet Access
• MSP	Mobile Service Provider
• PB	Petabyte
• QoE	Quality of Experience
• QoS	Quality of Service
• RAN	Radio Access Network
• ROI	Return on Investment
• TCO	Total Cost of Ownership
• VDSL	Very High Bit Rate DSL
• W-CDMA	Wideband Code Division Multiple Access

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About the Author

Olivier Guéret is senior marketing manager in the Network Optimization and LTE Service Practice at Alcatel-Lucent. In this position, Guéret contributes to the definition and promotion of services, helping operators maximize network asset usage and prepare the transition to LTE. Prior to that, Guéret held positions in wireless product marketing and product management. Guéret started his career in 1998 with Nortel and joined Alcatel-Lucent in 2007 during the acquisition of Nortel's 3G assets.

Guéret graduated from the *Ecole Nationale Supérieure des Télécommunications de Bretagne, France,* and holds a Master of Science degree in telecommunication systems and signal processing from the *University of Bristol, U.K.*

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