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Navigating the Small Cell challenge: Scaling by a factor of 10

White Paper

November 2013

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What's driving the need for Small Cells

Henry Ford is credited not only with introducing the Model-T Ford, but the manufacturing methods and processes that enabled large production volumes at low cost. Often overlooked, he also paid his workers well above the going rate – reflecting the higher gross margins he was able to make through efficiency savings.

The mobile industry is about to go through a similar major disruption for data volume and cost per bit. Forecasts such as Cisco's VNI[i] warn that wireless data consumption will grow by a factor of 13x between 2012 and 2017, having doubled annually in recent years. Few expect significant extra revenues to be generated from the data traffic itself.

To some extent, network operators have circumvented more recent capacity growth, encouraging offload to Wi-Fi in the home and office, expanding existing cell sites to their maximum capacity, refarming 2G spectrum for 3G and introducing LTE in its own additional spectrum. Around 50% of smartphone data is offloaded to private Wi-Fi[ii] – perhaps far more than most end users realize.

But there are limits to how far each of these approaches can go. A group of 3GPP experts examined the problem in June 2012, reporting[iii] that there were limited further gains to be had purely from additional spectrum or greater spectral efficiency. In order to meet projected demand for anything up to 1000x today's traffic density, spatial frequency reuse would be essential – effectively by deploying very large numbers of small cells. Analyst surveys[iv] confirm that the majority of operators are planning to expand their traffic capacity by at least 20x before the end of 2017, with a significant group aiming for more than 50x current levels.

Estimates vary widely on the number and scale of small cell deployment. Ratios of small cells to macrocells of anything from 4:1 to 10:1 or higher are quoted for dense urban traffic areas. The majority of small cells will be installed indoors, closest to the highest traffic usage. Millions of femtocells have already been installed for residential use, primarily to solve coverage problems.

In future, capacity will be the main driver and the total cost of each public access small cell (including site rental, power, installation and management) will be higher than for residential femtocells. Analysts forecast that over 20% of the capital expenditure on radio access networks will switch to small cells within the next 3 years. Given the much lower unit cost per small cell, this quickly translates to large numbers of installations. The effectiveness and efficiency of their deployment will become a major differentiator between wireless network operators.

One South Korean operator is estimated to deploy over 100 LTE small cells every day, ramping up from an installed base of 6,000 to 18,000 in just 6 months. By contrast, many mature macrocell networks today deploy fewer than 100 new macrocell sites per month.

Cell Type	Urban Macrocell	Public Access Small Cell
Typical Number required for busiest 1km^2 area	7 Macrocells provide coverage	42 Small Cells provide capacity
Range	2km or more	~100m
Backhaul	Mostly fiber	Mostly mix of wireless
Deployment process	Lengthy site selection, negotiation, construction	Rapid site selection and deployment

The three critical factors of change

During the 1980's and 1990's, the computer industry underwent a period of dramatic upheaval from mainframe, minicomputer and PC. Small cells could have a similar impact on how mobile operators plan, deploy and manage their networks.

Three critical factors are essential to support this:

- **Deskilling**: Enabling a wider pool of installation staff. Large numbers of equipment mean that the level of expertise required to install, configure and optimize must be reduced. Specialist skills will be reserved for strategic planning, difficult fault finding and unusual situations. A satellite TV dish installer should be capable of commissioning a small cell.

- **Velocity**: Automated processes are essential. The elapsed time between determining where and when to deploy any small cell until it goes live has to be days rather than months. Network optimization also needs to become more reactive and responsive to frequent equipment, end user device and usage pattern changes.

- **Precision**: Location is key. The short range of each small cell makes it more important to determine accurately where they are placed and how they are configured to achieve a good ROI (Return on Investment).

Even where separate frequencies and/or radio technologies are used for macro and small cells layers, optimization is still required to ensure a clean, smooth, consistent and efficient service is delivered to mobile devices. Neighbor lists, where and when to encourage/enforce handovers, become both complex and critical. The choice of frequency bands, radio technologies, power levels, antenna tilt angles further adds to the complexity.

The result directly affects both customer experience and network efficiency – in turn impacting competitiveness and the bottom line.

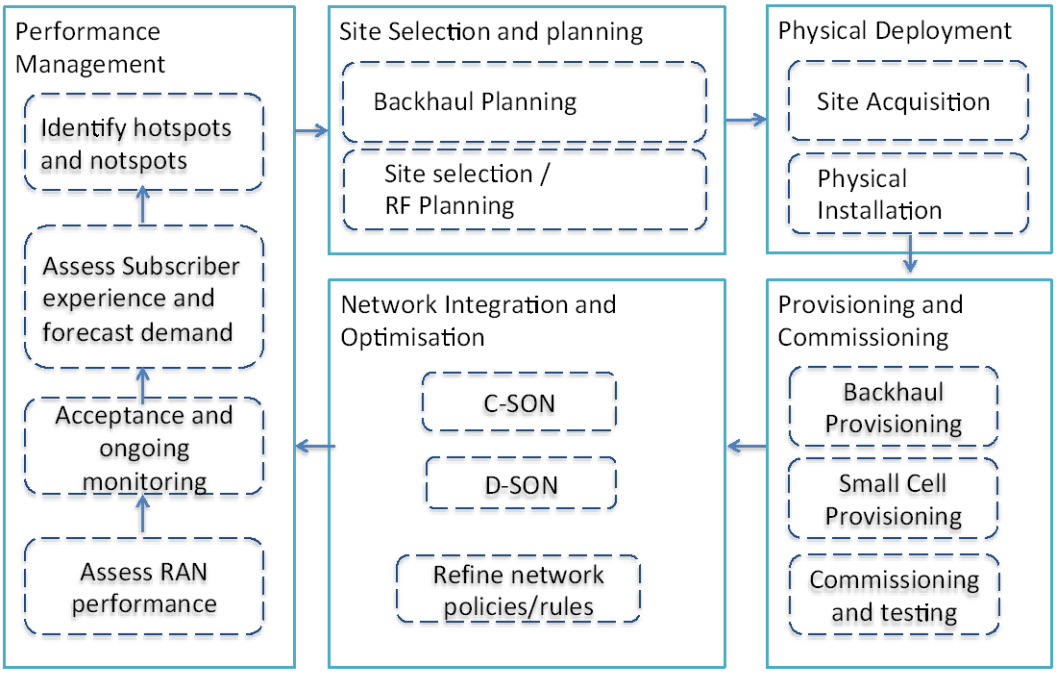
Three affected areas of planning and operation

The operational impact of large scale small cell deployment will affect three primary areas of operation:

- **Site selection**: Determining where and when to install new, upgrade existing or retire old equipment.
- **Deployment**: Implementing these physical network changes in the field.
- **Management and monitoring**: Configuring and optimizing network parameters to achieve optimal performance, adapting to frequent equipment changes, identifying, prioritizing and resolving faults.

Many industrial factories would find it challenging to double production rates without adapting their current processes. The implications for mobile operators who need to scale by a factor of up to 10 with 2-3 years may be much more dramatic.

The diagram below illustrates the end-to-end process for small cell site selection, deployment, integration and ongoing performance monitoring.



Site selection

Today's macrocell planning process

Today's RF planners rely predominately on a variety of performance management reporting tools to identify traffic capacity and coverage hotspots. Theoretical predictive analysis using RF planning software is then used to assess the ideal location for any new site, and compare between different options. Often these systems are independent, requiring a "swivel chair" approach with frequent data re-entry.

Onsite surveys then report back with several commercially available options, and further theoretical analysis is used to select based on both total cost and performance.

The order can then be given to acquire, build and commission the site which may take weeks or months to come online. While cycle times have reduced in recent years, relatively inefficient manual processes involving multiple departments and outsourcing companies are not yet ready to scale up to meet the volume required.

Fully understanding today's network usage

With small cell coverage footprints of 100m or less, targeting the location accurately makes the difference between a new installation delivering a good ROI or being a worthless distraction. This has led to a range of geo-location based reporting tools, which correlate RF measurement reports from end-user devices to pinpoint the source of traffic. Accuracy levels of 50 to 100 meters are achievable, with further refinement from GPS geo-located services such as Twitter and/or correlating with visible Wi-Fi networks. Reports can be filtered based on time of day, device type, service used and many other factors.

Some local knowledge, common sense and intelligent interpretation of usage reports can then be used to qualify the results. Often, network planners will say they can make a good educated guess of where the traffic hotspots are and expect many of these same areas to grow in traffic demand at similar rates to elsewhere. But with changing usage patterns, device types and innovative new services, the future is hard to predict. A comprehensive, accurate and detailed insight into current network usage is an essential capability to identify critical hotspots and changing network usage patterns.

A small but growing proportion of wireless data is offloaded to Service Provider Wi-Fi, and some operators have invested heavily in both their own and partner Wi-Fi access. Often mobile operators have little visibility of where, when and for what purpose their customers use Wi-Fi. This can make it difficult to assess where today's weaker cellular service areas are adequately augmented by Wi-Fi or where a new Wi-Fi roaming partner might make a better fit than new cellular equipment.

Determining where and when to deploy new small cells

Three methods of assessing the benefit of a new small cell are:

- **Traffic volume handled in Gbytes per day**. Where heavy users are in close proximity to the small cell, the full benefit of higher modulation schemes can deliver peak data rates. Forecasting achievable data

rates from the RF conditions increases not just traffic capacity but end user satisfaction from the higher speeds.

- **Traffic resources released from the macrocell**. Disproportionate RF capacity is needed to deliver data at the cell edge, penetrating in-building or around street furniture. The cost of a Gbyte of data at the cell edge can be far higher where advanced higher order modulation techniques can't be used. Proper analysis can justify a better ROI for small cells with lower total traffic throughput than others, when considered in this wider HetNet context.

- **Value of traffic handled**. Where it is possible to associate the end user value for the data used, a closer link to the true ROI can be achieved. Aspects can include assessing the types of service being used (roamers vs. business email vs. recreational video) and/or relating to the customer ARPU.

Not all small cells are deployed purely for capacity reasons. Filling in coverage hotspots and improving service quality are also important metrics for any mobile network. In these cases, higher availability will be a factor, especially the choice of backhaul used.

Again, the precision and resolution of network usage data is essential to make better planning decisions. Strategic issues which affect the site selection and choice of equipment type include:

- **Radio technology**: Ideally all of 3G, LTE and Wi-Fi would be included, but that impacts the total small cell cost, power consumption and backhaul capacity. A strategic plan needs to take account of anticipated device migration and usage of LTE, which may differ between indoor and outdoor usage.

- **Wi-Fi offload**: Some operators may seek to offload high consumption of "recreational video" usage to Wi-Fi, focusing their higher quality and more robust cellular service on voice and non-streaming data. Others may prefer to invest in LTE capacity to deliver a more controlled and repeatable service for all.

- **End user device**: With the majority of smartphones still being heavily subsidized through end user contracts, device upgrade policy and planning of the migration to LTE is closely tied to small cell deployment. Some European operators forecast a slower adoption of LTE, and may invest in more 3G small cell capacity in the short term, while US/Japanese/South Korean networks appear to be prioritizing LTE.

- **Indoor vs. Outdoor**: With increased wireless data consumption moving indoors, the traditional approach of delivering service from outdoor macrocells is becoming much less efficient. There are different views on whether it is more cost effective to deploy small cells in the streets to penetrate in-building, or to deploy dedicated in-building small cell networks. In practice, both are likely to co-exist.

Today's classic site planning cycles are too long

Multi-national group procurement has streamlined the wide variations in macrocell specifications in recent years, standardizing and simplifying the configuration choices across multiple countries. This has allowed manufacturers to reduce the number of variants produced, stocked and shipped – passing on the cost savings to operators. A similar common set of small cell product specifications may also allow the industry to compete on the same terms, differentiating through software and additional optional value added features.

Backhaul procurement can also benefit from greater multi-national commonality. Wireless backhaul can benefit from common spectrum policy and allocations, reducing the necessity to build or design different equipment variants. Access to backhaul will become a more important aspect of small cell site selection, especially in street canyons and other awkward locations.

Setting up tiger teams

The densification of the network will be initially constrained within the busy Central Business Districts of urban metropolitan areas, public venues such as sports stadiums and larger corporate campuses.

Many mobile operators will setup dedicated planning teams to focus on these locations, with a remit to handle:

- Indoor and outdoor locations
- 2G/3G and LTE technologies
- Macro, micro and small cells
- Backhaul

Experience has shown that for outdoor coverage, independent small cell planning teams may not work so effectively as might be expected. The entire HetNet including both macro and small cell layers needs to be closely coordinated and planned holistically.

Indoor locations are a different prospect. The construction materials used for many modern buildings provide strong RF isolation and may justify an independent planning team, where interaction is engineered only at the entrance and exit points.

Service Provider Wi-Fi is another option to relieve data capacity. This is more likely to be engineered and delivered by a different department, with roaming and outsourcing reducing the control of where and when new hotspots are deployed. Small Cells with integrated Wi-Fi, or upgrading existing Service Provider Wi-Fi points to become full small cells, will require closer co-operation between such departments. It is not unheard of for some fully Wi-Fi capable small cells to have had this capability disabled for political rather than technical reasons.

Many operators have already setup a focus team (or assigned clear individual responsibility) for end-to-end latency through the network. There isn't much point in deploying the latest LTE-Advanced radio equipment if the path to the Internet involves heavy or inconsistent delay and bottlenecks. This has brought much better

understanding of the tradeoffs between higher throughput/low latency against higher availability, resource sharing, security and cost.

Inputs to the small cell site selection

A variety of data sources can be used to achieve the higher precision required to target small cells:

Call traces and RF measurement reports: Originating from active mobile devices and relayed via the RNC, these provide almost real-time RF signal strength and interference measurements for all active voice and data sessions. In addition, each dropped and blocked call is captured along with the underlying cause – coverage, capacity or mobility. This data can be geo-located, translating these measurements into accurate heat maps that reflect subscriber demand and the network quality they receive. Call traces also establish where active sessions were forced to handover to other network technologies such as 2G or were lost completely.

Call records: Billing records and related subscriber data provide insights into subscriber and call value. These insights when tied to locations and network elements add commercial insights that enable operators to assign a monetary value to geographic locations. This improves ROI (Return on Investment) calculations and investment trade-offs.

Geo-tagged tweets and other social media. Accurately sourced activity based on device based location services (including GPS), which can be profiled and assessed to determine traffic hotspots. These OTT data sources have the benefit of cutting across all operators providing insights into both demand but also coverage holes.

Drive and walk testing: Live measurements from both indoors and outdoors in the street provide another source of actual performance. Some innovative operators have installed test equipment in city taxis, which upload live test results during their frequent travels around the city.

Crowdsourcing Apps: Various smartphone applications measure and report consumer performance results with location tracking. These are quite sophisticated, monitoring the end-to-end data service, taking into account time of day, location and other factors. In many ways, these represent more closely the service quality and performance seen by each end user.

Many radio planners would say that they already know where their traffic hotspots are today. In the future, such hotspots may appear or move quite rapidly, and end-users adopt different usage profiles, install different Apps and adopt LTE.

What does it take to deploy 10,000 small cells?

Today's process for deploying a large macrocell site typically involves multiple departments, many highly skilled professionals and a lot of elapsed time.

A quite different approach is needed if networks are to install 100 small cells per day.

Driven from clear planning requirements that have assessed ideal small cell locations, onsite surveys need to be fast and pragmatic. We could learn from the SP Wi-Fi industry, where field staff identify and refine optimal positions recorded using an iPad application. Skilled surveyors can assess coverage and quickly account for factors including line-of-sight backhaul, anticipated environmental changes (growing tree lines, buses, footfall etc.).

A wider choice of real-estate will help, driving strategic partnerships with site owners, resellers, local councils, fixed telecom providers amongst others.

Skillsets for installation

The industry often refers to a Satellite TV installer to indicate the typical level of skillset appropriate for straightforward outdoor small cell installation. This combines the physical ability to climb a ladder and install a box on a wall or pole, adequate knowledge of radio and electronics to align the antenna, connect mains power and commission line-of-sight backhaul. This mix of skills is widely available and cost effective.

Some councils restrict access to certified and known workmen, especially where electrical work is required, such as for light poles. Constraints may also apply to the time taken for the installation – if street traffic is affected for more than 15 minutes, special permission, notifications and procedures apply.

Small cell vendors report that after just 2 hours of training, council electricians have successfully installed outdoor small cells and backhaul, quickly and efficiently.

Indoor installation, in an office or public venue, is a different matter. Internal Ethernet wiring is used for backhaul rather than wireless links. Sub-contracted or in-house electricians are quite capable of fitting and connecting small cells throughout large buildings, provided their location has been clearly specified beforehand. The minor additional cost of installing a few additional indoor small cells quickly offsets any inefficiency in the design and allows some flexibility for future expansion.

Greater automation of the configuration process

Once installed, simple checks can confirm that the installer has completed the work satisfactorily. An end-to-end speed test validates the backhaul link, while a self-test ensures the equipment is working correctly.

This is the point where sophisticated provisioning and configuration software is essential. In the past, macrocell commissioning could involve on-site specialist teams manually downloading a test configuration and performing a series of drive tests. Thereafter, a series of manual configuration and optimization tasks would be performed by a regional planning team to integrate the new cell site with its neighbors.

Self-Organizing Network (SON) technology is evolving to automate much of this process, as evidenced by today's residential femtocells. These identify, authenticate and register themselves before downloading the latest software and default configuration. Using local intelligence, sometimes called Distributed SON, they sniff out neighboring cells and determine which frequency, RF power level and neighbor list to broadcast on.

Individual small cells don't have the full picture of all network activity in their area – the co-ordination between layers is too complicated to manage - and so Centralized SON (C-SON) is used to oversee and co-ordinate the parameters used for both small cell and macro cells in the same area.

A good example of this in the real world can be found in South Korea, where a SON Server[v] automates frequent configuration adjustments to the network as it adapts to the many new small cells and other changes made daily. RF power levels may be reduced in neighboring cells to favor a newly introduced cell. Potentially long neighbor lists can be shortened and optimized to establish preferred handover paths.

Automation is also needed to keep track of the full network inventory, so that the location, physical capability and backhaul connectivity is known. Site ownership, rental agreements and related commercial aspects are also important to ensure fiscal responsibility. Operators often don't have good software solutions or processes in place to do this today, leading to inefficiencies.

Monitoring and managing a large scale small cell network

NOCs (Network Operations Centers) have to identify, prioritize and respond to network outages 24x7 every day. They have to fit in planned outages, such as software upgrades, alongside reacting to unplanned ones. Teams are measured by how quickly they resolve faults, often using temporary workarounds until physical equipment changes can be made.

With many small cells providing extra capacity, rather than basic coverage, outages and faults may often become less critical to resolve so quickly. Service may be able to fall back on the macrocell layer which has enough spare capacity to infill for occasional underlying outages, especially where more of the macrocell traffic has been offloaded to other small cells.

SON technology can respond to such outages, working around the problem and continuing to deliver good service throughout. This will make it more important that NOC staff can fully understand how the network is reacting to individual problems, determine how critical the situation is, and prioritize remedial action accordingly.

A separate team of radio planners and optimizers will be looking carefully at a range of Key Performance Indicators (KPIs) to ensure that the network is performing efficiently and effectively. While SON systems should be making the best use of available spectrum, equipment and usage patterns, these algorithms themselves need oversight and tuning. Of course it's not only the RF link that needs to be managed carefully, backhaul bottlenecks also dramatically limit peak throughput and a full end-to-end capacity and latency analysis is essential to avoid unknown or unexpected poor throughput.

At an even more strategic business management level, network operators determine how quickly they want to adopt new technologies, such as LTE, LTE-Advanced or augment capacity through Wi-Fi. Investments involve not just network equipment, but also new smartphone devices and commercial partnerships. These strategic

decisions strongly impact policies used by planning, deployment, operations and maintenance staff throughout the organization.

Small cell acceptance

A critical milestone for any new cell site is its formal acceptance into the network. This is especially important when using contractors, for example when large numbers of new or upgraded base stations have been deployed. Often a lot of money rides on demonstrating meeting a specific set of KPIs, and it is not unusual for specialist RF engineers to become involved towards the critical phase of such projects.

Actix's LTE Acceptance for Small Cells solution has already been deployed with several North American operators where it is supporting their rollouts of Small Cells and DAS (Distributed Antenna Systems).

Small cells present significant challenges to mobile operators as the sheer scale of deployments force operators to look for mechanisms to increase the speed and precision of their deployment including acceptance procedures.

A critical part of the success of rolling out small cells will rest on delivering a high quality day one customer experience. To achieve this, operators need to ensure the rollout fulfills its capacity and coverage requirements while not adversely affecting the radio performance of their macro network.

To achieve scale, operators will rely on equipment providers and/or other third parties to carry out the rollout process, specifying SLAs (Service Level Agreements) to control quality. There will be strong commercial pressure on the third parties responsible for rollout and commissioning of new equipment. This could lead to some sacrifice of network quality to meet budget and time constraints. Oversight of performance metrics is essential to ensure that the full value and benefits of large scale network upgrades and small cell deployments are achieved. Operators will need highly scalable solutions that can ensure network quality without introducing unnecessary delays.

With the reduced skill level and move to SON automation, we may see a wider gap between acceptance of the physical small cell installation and that of a completely integrated HetNet. Sub-contractors would expect to be paid as soon as each small cell had been physically installed with power and backhaul verified to be working. Larger system integrators would then take responsibility for meeting defined KPIs, determined during the design phase, and work with operator's planning teams to ensure they are achieved.

Some operators may prefer to outsource their small cell design and deployment to a complete end-to-end supplier while others pick from the best of breed and assemble their own eco-system. In both cases, some level of planning and auditing tools will be essential for operators to manage the deployment process and measure its success.

Where Actix and partners play a role

Accurate site selection

Carefully identifying and prioritizing the best locations ensures 'right first time' deployment of small cells. Actix uses a combination of radio, subscriber geo-location and business insights to improve the quality and speed of decisions made.

Streamlined deployment

Large scale deployment of small cells requires stringent project management across multiple projects involving hundreds of people. Amdocs provides a highly flexible project management methodology which can quickly adapt to changing requirements while continuously monitoring complete end-to-end process flows. Task and project data can be viewed and updated directly by field staff throughout the installation and commissioning process.

Accurate measurement and optimization of small cell impact

Actix enables operators to measure and control the impact that their small cell rollouts have on customer experience and macro networks. By measuring accurate KPIs, operators can manage the SLAs between their network equipment providers to ensure day one quality. Optimization of the resulting HetNet ensures a seamless customer experience.

Conclusion

It is clear that the mobile industry will need to quickly adapt to the growing thirst for wireless data services. Many operators are planning for huge capacity increases of 20x or even 50x today's levels. Constraints on spectrum and spectral efficiency mean that this growth will primarily come through deployment of large numbers of small cells.

Scaling up today's operational processes and software tools to deploy hundreds of public access small cells on a daily basis will force substantial disruptive change. High levels of automation, streamlined operational processes and partner eco-systems will be essential to achieve rapid rollout and ongoing management.

There are three critical factors:

- **Deskilling**: Enabling a wider pool of installation staff, reserving specialist staff for unusual and high value activities.
- **Velocity**: Automating processes and reducing the cycle time from identifying a need and commissioning new equipment.
- **Precision**: The short range of each small cell emphasizes the accuracy and tight tolerances for best ROI.

The end user perception of network performance is becoming a greater differentiator. Achieving this cost-effectively and efficiently is the challenge which will determine the future competitiveness and profitability of mobile network operators. Those who are better prepared stand a greater chance of winning the battle ahead.

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[i] Cisco VNI Forecast: http://www.cisco.com/en/US/solutions/collateral/ns341/ns525/ns537/ns705/ns827/white_paper_c11-520862.html

[ii] Understanding the Role of Managed Public Wi-Fi (Feb 2013), Mobidia http://www.mobidia.com/products/whitepaper-download/

[iii] 3GPP Workshop on Future Radio, June 2012: http://www.3gpp.org/Future-Radio-in-3GPP-300-attend

[iv] Managing the new mobile network, Rethink Research, http://www.osstransformation.com/The-changing-shape-of-mobile-networks

[v] Interview with SK Telecom, ThinkSmallCell, http://www.thinksmallcell.com/Femtocell-Interview/thinksmallcell-interview-with-kim-chang-young-senior-manager-of-access-network-lab-sk-telecom.html