TD-LTE Network Evolution With In-band And Out-band Micro Cells Deployment

Zhao ZhuYan (1), Wang Jian (1), Guan Hao (1), P.E. Mogensen (2), Liu GuangYi (3), Shen XiaoDong (3)
(1) Nokia Siemens Networks Beijing, P.R. China, (2) Nokia Siemens Networks -9220 Aalborg, Denmark,
(3) China Mobile Research Institute (CMRI), China Mobile Communications Corporation (CMCC), Beijing, P.R.China
Email : (1,2) {zhuyan.zhao, jian.7.wang, hao.guan, preben.mogensen}@nsn.com ,
(3) {liuguangyi, shenxiaodong}@chinamobile.com

Abstract— **the wireless network gradually changes from voice service to broadband data access services and faces unprecedented growth in data traffic. The way to meet future capacity demand is by combining macro site expansion and outdoor micro layer deployment. Thus it is important for the operator to understand the basic cost and performance of different combinations of technologies according to their own network. In this paper, year-by-year network performance is simulated for an example TD-LTE network by using four networks upgrade approaches, including carrier upgrade, macro densification, micro deployment in dedicated carrier and micro deployment re-using macro carrier. Downlink TD-LTE network capacity evolution is analyzed in terms of the needed network upgrades. That is, we examine the number of macro and micro site need to be upgraded or added in each year for different network evolution paths, while a given network key performance indication (KPI) is maintained. The network cost in terms of relative Total Cost of Ownership (TCO) is then compared among network evolution paths.**

Keywords- TD-LTE; Network evolution; micro site, system simulation.

I. INTRODCUTION

The wireless network gradually changes from voice service to broadband data access services. Driven by attractive mobile internet applications and more capable mobile devices, the global mobile data traffic is expected to continue to double every year through 2014, leading to a global compound annual growth rate of 108% [1]. There are several network upgrade approaches that can be taken to meet traffic and data rate growth demands. Macro site expansion is widely used in existing 2G and 3G networks. It consists of deploying additional radio carriers for the macro site which spectrum is available, and/ or macro densification, in which the coverage of a macro cell site is divided into two or more new cell sites. Complementing the existing macro cell site with low power outdoor micro sites offers an alternative to macro site expansions. The macro layer provides good coverage, and the micro layer provides additional high capacity in smaller high-traffic hotspot areas. One of the basic issues with micro site deployment is how to determine the spectrum to employ in each cell layer .There are two spectrum assignment options for micro layer deployment: one is in-band micro cell deployment, in which macro layer frequency is reused by micro site, the other is out-band micro cell deployment, in which micro site is deployed using a dedicated carrier. The way to meet future capacity demand is by combining macro site expansion and micro layer deployment. Thus it is important for the operator to understand the basic cost and performance of different combinations of technologies according to their own network e.g. radio access technology, traffic growth anticipation and economical model when designing future wireless access networks.

A method used to analyze the long-term scalability of the network capability was described in [2]. Year-by-year network evolution forecast was performed based on a realistic HSPA network. The business impaction of network evolution was also analyzed for macro site expansion and micro layer deployment options. But only out-band micro cell is considered in the study. The simulation of network evolution by using realistic network scenario has been addressed in [3] [4]. The studies were limited on network performance analysis.

TD-LTE is considered as the evolution of Time Division-Synchronous Code Division Multiple Access (TD-SCDMA). Although TDD and FDD modes of LTE share the same underlying framework, some differences of TD-LTE from deployment perspective may affect LTE to get different results. One example is that in China, TD-LTE network is advisable to use 8 element cross-polarized antennas for beam forming. System performance of TD-LTE network has been analyzed in, e.g. [5] [6] using regular deployment scenario. TD-LTE network upgrade in realistic network has been addressed in [7], considering only macro site expansion.

In this paper, the simulation method described in [2] [3] [4] was used to study the network upgrade path of TD-LTE network considering beam forming gain. A CMCC network located in dense urban area is used as study case, where the existing TD-SCDMA and GSM macro site location are used as the TD-LTE macro site location. Year-by-year network performance is simulated for downlink with four TD-LTE network upgrade approaches, including carrier upgrade, macro densification, in-band micro and out-band micro deployment. Downlink TD-LTE network capacity evolution is analyzed in terms of the needed network upgrades. That is, we examine the number of macro and micro site needed to

978-1-4673-0990-5/12/$31.00 ©2012 IEEE

be upgraded or added in each year for different network evolution paths, while a given network key performance indication (KPI), e.g. network outage probability,, is maintained. The network cost in terms of relative TCO is then compared among network evolution paths.

The rest of the paper is organized as follows. In Section II, the techniques of TD-LTE network evolution are summarized. Thereafter, we present the used simulation scenario and model in Section III, and simulation results in Section IV. Finally, the paper is concluded in Section V.

II. TD-LTE Network Evolution and Techniques

In the study, network outage probability is used as KPI for network upgrade. Let R(u) model the average throughput of an arbitrary active user u, then the network outage Pout is defined as:

$$P_{out} = \Pr[R(u) < R_{\min}] \tag{1}$$

Where, R_{min} is the minimum data rate required for users to be admitted. In the case that network outage probability in the area is larger than a threshold such as 5%, the network configures will be upgraded.

In this study, TD-LTE network upgrade simulation focuses on both traditional macro site expansion which includes spectrum upgrade and macro densification, and micro site deployment which includes in-band and out-bands micro cell deployment.

- **Spectrum upgrade** is to deploy additional radio carriers for the macro site with high outage rate. Usually, spectrum upgrade is the most efficient network upgrade solution [7]. However, the spectrum assigned to any mobile communication system is limited, and the capacity offered by spectrum upgrade will no longer be sufficient as the traffic growth. In the study, we assume that two 20MHz carriers at 2.6GHz and 2.62GHz are available for TD-LTE deployment.
- **Macro densification** is to introduce more Macro sites in the outage area. Deploying new macro sites is usually much more expensive than other network upgrade options, especially in dense urban areas where suitable sites may be hard to find.
- **In-band and out-band Micro deployment:** in the study, we assumed that micro BTS is configured with 1 carrier. For in-band micro deployment, macro layer carrier at 2.6GHz is reused with micro BTS. For out-band micro deployment, a dedicated carrier at 2.62GHz is used to deploy micro site. Macro layer is deployed at 2.6GHz with signal carrier when out-band micro deployment is used. Although the deployment cost of micro site is lower than the macro site, but due to the reduced range of low power nodes, a significant number of micro sites is required to cover the hotspots and coverage holes. Micro layer deployment cost which mainly includes backhaul transmission, cell management and site maintenance will increase with the number of micro sites.

The network upgrade approaches described above were assumed to be implemented in a sequential order to create different TD-LTE evolution paths. In the study, we consider the following 3 TD-LTE network upgrade paths (upgrade approach combinations)

- **Path 1 (Macro densification):** spectrum upgrade-> macro densification
- **Path 2 (In-band Micro deployment):** spectrum upgrade-> in-band micro deployment
- **Path 3 (Out-band Micro deployment):** out-band micro deployment

For the evolution path 1and path 2, the network evolution path includes 2 steps. In the first step, the macro sectors with high outage user density will be upgraded to the 2nd carrier. If the outage is still higher than 5% in the area, new macro site, or in-band band micro site will be deployed to fulfill the performance requirement in the second step. For the evolution path 3, out-band micro sites will be deployed in the high outage user density area in the first step. The deployment of macro/micro site follows a formula described in [3], in which the new site position is selected according to the outage rate, user density and signal strength characters.

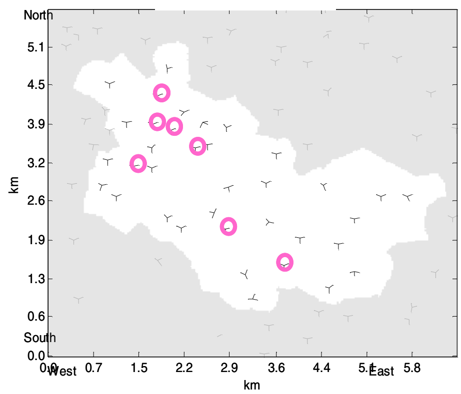

Figure 1. Case study network. The grey part is the mask of the outer tier site. Existing TD-SCDMA and GSM macro site locations are depicted, inter site distance is 400m (The circle represents the GSM site)

III. Simulation Scenario and Model

In this section we describe the simulation scenario and basis of the underlying simulation model. The simulation model descriptions focus on downlink.

A. Reference Network

The reference network in the case study shown in figure1, is an approximately 5x6 km area located in a major city center of China. The existing TD-SCDMA site information such as site position, antenna height, and antenna direction is used as initial configuration of TD-LTE network. GSM sites which are not co-located with TD-SCDMA sites are selected to complement TD-LTE sites. The antenna configuration of GSM site is set for TD-LTE network. To avoid boundary effects, a mask was defined for the dominance area of outer tier sites. The sites and users located in the mask area were considered as interferers only, and their statistics were not counted in the results. In total there are 36 valid TD-LTE sites, which is 108 sectors, located in the inner tier. The average inter site distance is around 400 m.

B. User Distribution

The users in the network were randomly dropped according to the spatial user density function $\lambda^u(x,y)$ [users/km2] for a coordinate {x, y}. In the simulation, the spatial user density is generated according to the traffic density which is obtained from the existing network cell level traffic measurement. We assume that average offered throughput per user during busy hour is the same for all active users and is equal to s [bits/s]. The spatial user density can then be calculated by $\lambda^u(x,y) = \lambda^s(x,y)/s$, where $\lambda^s(x,y)$ is the throughput density. From the traffic density map of the study network, small percentages of sites carry a large fraction of the overall network traffic. Thus some sites have dropped denser active users during simulation as hot spot. When we simulate the TD-LTE user number increasing with network operation years, we assume that the inhomogeneous user distribution keep constant.

C. Physical Layer

In the simulation we assume that the TD-LTE eNB, which includes both Macro site and micro site, is time synchronized and uses the same downlink/uplink configurations. The user SINR in downlink is calculated as:

$$SINR_{UE(m)} = \frac{G_{Ant(i)} PL_{(eNB(i)->UE(m))} P_{t\_eNB}}{N_{UE} + \sum_{j\in K\setminus i} (G_{Ant(j)} PL_{eNB(j)->UE(m)} P_{t\_eNB})} + G_{BF} \tag{2}$$

Where G_{Ant} is antenna gain of both transmitter side and receiver side, $PL_{eNB(i)->UE(m)}$ denote the path gain from base station i to user m, the set k includes all base stations at the same channel, P_{t_eNB} is the base station output power, N_{UE} is the UE's noise power. G_{BF} is the additional SINR gain from 8 antenna beam forming. As macro site is configured with 8 elements antenna and Beam forming is used on the traffic channel. We assume G_{BF} is 4 dB for traffic channel transmission in macro site and 0dB for micro site and control channel transmission .

$$G_{BF} = \begin{cases} G_{BF} = 4dB, & \text{if traffic channel in macro site} \\ G_{BF} = 0dB, & \text{if micro site or control channel} \end{cases} \tag{3}$$

When G_{BF} is 4dB, the throughput of cell edge UE and cell center UE is increased by 100% and 30% respectively according to the SINR/ throughput mapping curve.

The Macro link propagation loss was calculated with the COST-231-Hata model. The Micro link propagation was calculated according to 3GPP model [8]. The UE accesses the TD-LTE eNB according to received signal strength of control channel. The user data is calculated according to the average received SINR and assigned radio resource as described in [2][4]. A data rate control algorithm was implemented to minimize the outage in each cell for a given of amount radio resource available per cell. .

IV. SIMULATION RESULTS

In the case study, a traffic growth model was used to demonstrate the TD-LTE network configuration evolution for four consecutive years of roll-out phase. Year-by-year active user number of the studied network and minimum required data rate were given in table I. Form the table, the active users in TD-LTE network increase ~ 20 times within 4 years and the minimal required user data rate is 1Mbps.

TD-LTE network evolution was simulated in network roll-out phase. In the initial stage (1st year), TD-LTE Macro base stations were configured as 1+1+1, which means that each site contains 3 sectors, and each sector is configured with 1 carrier. Then TD-LTE network configurations were upgraded with the active user number growth, and guarantee that the network outage P_{out} is less than 5%. We examine the number of macro and outdoor micro site needed to be upgraded or added in each year for the 3 network evolution paths described in section II. By comparing the relative cost of these upgrade scenarios over the four consecutive years, we can derive the cost value of deployment options from a business perspective. Common system parameters were given in Table II and base station class specific assumptions were summarized in Table III.

Cost coefficients for adding a new TD-LTE Macro site and Micro site were given in Table II, normalized with the average total upgrade cost for 2nd carrier upgrading in a 3-sector TD-LTE macro site. The underlying cost model depends on a wide set of parameters being considered as one time costs as well as recurring costs. One time costs comprise CAPEX (capital expenditures) and IMPEX (implementation expenditures). CAPEX is related to initial investments such as equipment costs, while IMPEX addresses one time service costs for eg. planning and implementation. On the other hand, recurring costs are referred to as OPEX (operational expenditure) and they include costs for O&M (operation & maintenance), site rent, backhaul transmission, electric power etc.

TABLE I. ACTIVE USER NUMBER AND MINIMUM REQUIRED DATA RATE

Year	1st year	2nd year	3rd year	4th year
Active users	48	254	612	965
Min data rate	1Mbps	1Mbps	1Mbps	1Mbps

Appropriate site costs for acquisition, site preparation and rent were taken into consideration and derived from field experience. Site cost were only considered for new macro and micro deployment, whereas we assumed that site cost of TD-LTE Macro site is taken by co-located legacy network in the initial stage. Micro sites were assumed to be installed on walls of existing buildings or light pole and micro site use fiber network for backhaul transmission. The OPEX is assumed to calculate 5 years.

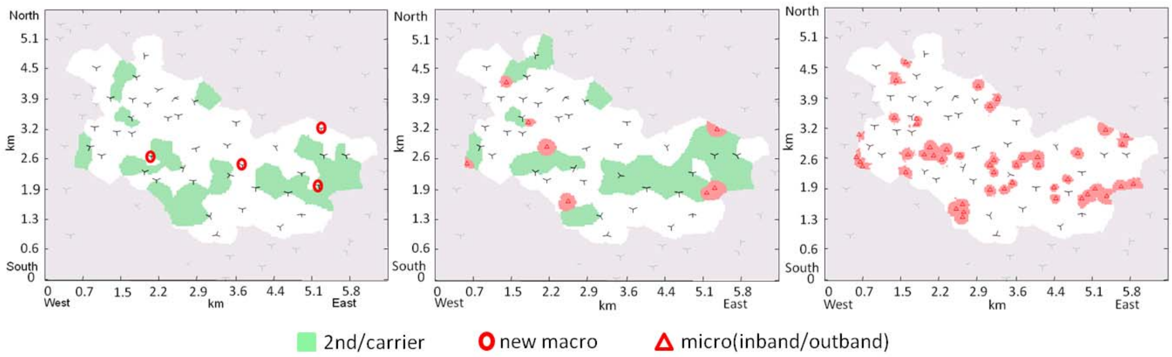

Figure 2. network layout and upgrade level in the 4th year (left: netowrk evolution path 1, middle: network evolution path 2, right : netowkr evolution path 3)

TABLE II. COMMON PARAMETERS ASSUMPTION

Parameters	Description
Frequency	2590MHz-2630MHz
Bandwidth per carrier	20MHz
LTE frame structure	TDD frame structure with normal CP
UL and DL ratio	44: 56
Indoor user percentage	Based on clutter map
Indoor loss	20dB

TABLE III. BTS SPECIFIC PARAMETERS

Parameters	Macro Site	Micro Site
Relative cost	2.81	0.71
Transmission power r	46dBm per carrier	37dBm per carrier
Antenna scheme	8x2 beam forming	Omni antenna
Max Antenna gain	14dBi	6dBi
Max configured carriers	2	1
Path loss model	Cost 231-Hata	3GPP [8]

A. *Results of Network Evolution*

The results for the network evolution path 1, 2 and 3 are listed in Table IV, Table V and Table VI, respectively. The network simulation shows that TD-LTE network re-use existing macro site was able to sustain traffic growth for the first two years. However, by year three, it was no longer able to meet growing capacity demands without significant upgrades. For upgrade path 1, 16 sectors, which represents 15% of total sectors, were upgraded to 2nd-carrier in the 3rd year. In the 4th year, the number of sectors upgraded to 2nd-carrier increased to 27, which is 19% of total sectors (including new added macro site), Besides that, 4 new macro sites were added in the network, which means 11% more sites than the initial TD-LTE site deployment. For upgrade path 2, the 2nd-carrier sector number is same with path 1, instead of macro sites, 8 new in-band outdoor micro sites were deployed in the 4th year. For upgrade path 3, out-band outdoor micro site deployment were required from the 3rd year. There are 14 and 47 out-band micro sites deployed in the network in the 3rd year and 4th year, respectively. All three network evolution paths satisfy the network capacity growth demand according to the set minimum data rate requirement (Table I).

Figure 2 shows the network layout and network upgrade level at 4th year. With the outdoor micro layer deployment, the micro sites were concentrated in high user density regions, and deployed in edge of macro cell. For upgrade path 2 in the 4th year, 7% macro sectors were configured with 1 micro site each. For upgrade path 3 in the 4th year, 20% macro sectors were configured with 3-4 micro sites each. Compared to the in-band micro deployment approach, more new out-band micro sites (~7.6 times) were required, and to be deployed one year earlier because low power micro site coverage is much smaller than the coverage of macro site using 2nd carrier.

Figure 3 shows the network throughput in the 4th year. Compared to no network upgrade scenario, network upgrade path 1, path 2 and path 3 results in 48.7%, 45.2% and 137.2% capacity gain, respectively. In order to meeting the total network outage requirement, which is normally 5%, more number of out-band micros are deeded than in-band micros. In consequence, together with higher SINR than in-band micros, out-band micro deployment shows higher network throughput than in-band micro deployment.

B. *Results of TCO Calculation*

Figure 4 shows the relative network cost of network evolution path 1, path 2 and path 3, which is normalized with network TCO of network evolution path 3. Evolution path 2 (in-band micro deployment), was calculated as the most cost efficient, and the network upgrade cost is 24% lower compared to the evolution path 3. Compared to evolution path 2, the cost of evolution path 1 (macro densification) is 18% higher because deploying new macro sites is much more expensive than micro site. Among three evolution paths, evolution path 3 (out-band micro deployment) gives the highest network cost. This means that macro site carrier upgrade is more cost efficient than micro site deployment. This is because high transmission power of TD-LTE macro site enlarges the cell coverage and 8 elements cross-polarized antenna beam forming efficiently increase the cell edge user throughput by concentrating signal strength in a specific direction to the user as well as minimizing the interference power from neighboring cells, at the same carrier upgrade does not increase the site cost.

TABLE IV. UPGRADE ROADMAP FOR EVOLUTION PATH 1

year	No upgrade (sectors)	2nd carrier (sectors)	new Macro (sites)	New Micro (sites)	outage
1st year	108	0	0	0	0.5%
2nd year	108	0	0	0	3.6%
3rd year	92	16	0	0	4.9%
4th year	81	17	4	0	5.1%

TABLE V. UPGRADE ROADMAP FOR EVOLUTION PATH 2

year	No upgrade (sectors)	2nd carrier (sectors)	new Macro (sites)	New Micro (sites)	outage
3rd year	92	16	0	0	4.9%
4th year	81	27	4	8	5.0%

TABLE VI. UPGRADE ROADMAP FOR EVOLUTION PATH 3

year	No upgrade (sectors)	2nd carrier (sectors)	new Macro (sites)	New Micro (sites)	outage
3rd year	108	0	0	14	4.8%
4th year	108	0	0	47	5.0%

V. CONCLUSION

In this paper, year-by-year TD-LTE network performances are simulated with three network upgrade paths, including macro densification, in-band micro and out-band micro outdoor deployment. The simulation results show that the TD-LTE network which is deployed based on legacy 2G and 3G sites supports the traffic growth well through carrier upgrade and proper macro site densification or micro site deployment in roll-out phase. These network evolution studies showed that 2nd carrier upgrade of TD-LTE macro site will boost the network capacity in large area, and be able to satisfy the network KPI requirements before the 4th year. After that, site densification, such as new macro site or micro site deployment, was required. Network evolution with hybrid carrier upgrade and in-band deployment which is indicated as path 2 was calculated as the most cost efficient among the three network evolution paths. In network evolution path 2, in-band micro sites instead of high cost macro sites were used to complement a 2nd carrier upgrade strategy in hot spot. Compared to in-band micro deployment approach, more new micro sites (~7.6 times) were required for out-band micro approach to satisfy the minimum date rate requirement. Network deployment cost of out-band micro is 31% higher than in-band micro deployment. It means carrier upgrade in existing TD-LTE macro site is more cost efficient than micro site deployments especially in network roll out stage. But out-band micro deployment provide the highest network throughput, and is easier from cell planning and radio resource management point of view.

For future work in this area, it would be interesting to investigate the impaction of advanced radio resource management scheme on in-band micro deployment.

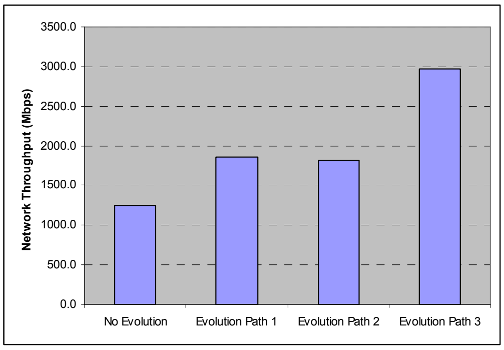

Figure 3. Network throughput in the 4th year

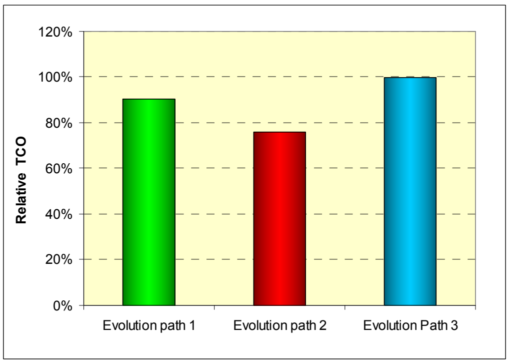

Figure 4. Relative network TCO of network evolution path1 , path 2 and path 3

REFERENCES

[1] Cisco VNI Forecast,“Cisco Visual Networking Index: Global Mobile data Traffic Forecast Update 2010-2015,” Cisco Public Information, February 1, 2011.

[2] Elling, J. et al., “Mobile Broadband Network Evolution Towards 2015 – A Copenhagne Area Case Study ,” Telenor Group,Telektronikk publications, January 2010.

[3] Colleti, C. et al., “Deployment of LTE In-Band Relay and Micro Base Station in a Realistic Metropolitan Scenario”, Proc. IEEE Veh. Tech.Conf., Sep 2011.

[4] Kovacs, I. et al., “Mobil Broadband Traffic Forecast Modeling for Network Evolution Studies”, Proc. IEEE Veh. Tech.Conf., Sep 2011.

[5] Mugen Peng and Wenbo Wang “Technolgies and Standards for TD-SCDMA Evolutions to IMT-Advanced”, IEEE Communicatins Magazing,vol.47. pp.50-58, December 2009.

[6] Xiao Yang, Yuexing peng, et al. “performance analysis of samrt antenna with mono- and dual-polarization in TD-LTE system, ”12th IEEE intrenation conference on Communication Technolgoy (ICCT), 2010, pp.151-154

[7] Zhao ZhuYan, Wang jian, et al., “TD-LTE Network Deployment Evolution in a Metropolitan Scenario”, Proc. IEEE Veh. Tech.Conf., Sep 2011.

[8] 3GPP TR 36.814, “Further Advancements for E-UTRA, Physical Layer Aspects,” version 1.5.1, December 2009