

Financial Benefit Analysis of Macro-Femto Network Structures Based on TCO Approach

Wafa Werda¹, Bo Gu¹, Kyoko Yamori^{2,3}, and Yoshiaki Tanaka^{1,3}

¹Department of Communications and Computer Engineering, Waseda University
3-4-1 Okubo, Shinjuku-ku, Tokyo, 169-8555 Japan

²Department of Management Information, Asahi University
1851 Hozumi, Mizuho-shi, Gifu, 501-0296 Japan

³Global Information and Telecommunication Institute, Waseda University
3-4-1 Okubo, Shinjuku-ku, Tokyo, 169-8555 Japan

{wafa.werda, bo.gu}@akane.waseda.jp, kyamori@alice.asahi-u.ac.jp, ytanaka@waseda.jp

Abstract— Mobile Network Operators (MNO) are nowadays facing an exponential growth in their network traffic, as more and more customers are having access to affordable new technologies using smarter and data-based equipments. As new strategies have to be developed and implemented in order to meet those demands in a cost efficient way, the offloading one, with using an alternative network to the macrocell cell network, has been under ongoing discussions and studies. More specifically, the femtocell offloading alternative has been pointed out as a potential cost effective solution regarding many advantageous specificities related to this technology like the small size and ease of installation, making it easier to deploy than the macro one. In this paper, we will assess the relative costs benefits resulting from deploying the femtocell network, using the Total Cost of Ownership (TCO) as an economical method to have more accurate and up-to-date results regarding those potential benefits. Cost analysis will be performed based on our base case scenario, and discussions on possible future extensions of this work are presented.

Keywords—Macrocell Network, Femtocell Network, TCO, DCE, Financial Benefits, Cost Analysis

I. INTRODUCTION

Mobile data traffic is widely experiencing an exponential growth, driven by the widespread of data capable devices, higher bandwidth applications, intense competition and commoditization of communications services

However, on the other side, this is not really being reflected on the network operator's revenues, since big disparities and considerable gap between traffic growth and generated revenues exist and are being under ongoing discussions. In fact, existent studies [1] show that operators' revenues are gradually decoupled from network traffic, where bandwidth requirements are far exceeding revenue growth. Especially from the beginning of the

data services era period, where this gap is constantly expanding. This puts tremendous pressure on network operators to cut several costs. In other words, if MNO fail to investigate and propose new schemes to maintain a healthy sustainable economic model, which will allow them to continue to invest to meet exploding demand, the showed gap will continue to grow.

Thus, MNO are now facing a big challenge of finding new alternatives in order to meet those increasing demands and limit their negative impact of requiring more network resources investment. They are evaluating many options like the deployment of more spectra to increase overall capacity, the enhancement of used technology and technical improvements, the re-evaluation of pricing strategies, but also by considering offloading strategies as an alternative to common traditional macrocell sites deployments. The last option is actually one of the most considered now by network operators. And one of the most considered offloading strategies is actually the deployment of femtocell technology, consisting of low-power and small-size base stations, making them easier to deploy than macro ones. Thus, they are now regarded as promising way to provide better coverage and capacity for cellular networks.

However, apart from the so discussed benefit of improving indoor coverage for indoor users, the important issue of reducing overall network costs when using femto cell networks by offloading macro traffic has been pointed out. The main reason for those cost saving benefits and perhaps the most obvious one, is that femto service deployment generates much more lower costs than the macro one (regarding their small size, femtocell site can be placed in any existent building, it uses the already set up wired backhaul to connect to the networks, etc.). Here, a rising question would be: Are femtocell networks always the most cost-efficient solution? When thinking about the deployment a femtocell as an alternative or as a mixed network with macrocell, what is the real cost benefits generated from such infrastructure?

In this paper, we will perform cost analysis of such macro-femto deployment infrastructure, using actual TCO (Total Cost of Ownership) economic approach, in order to get up-to-date and more accurate results concerning heterogeneous networks deployment and the assessment of eventual cost saving benefits in such kind of networks.

The rest of this paper is organized as follows. In section II, we describe our proposed economic models for macro-femto cellular networks. In section III, we present our infrastructure capacity modelling and coverage scenario. Section IV outlines the main findings and numerical results of our TCO approach to evaluate the generated cost benefits from adopting the femtocell offloading strategy. Finally, section V concludes this paper with a reference to our future work.

II. ECONOMIC MODELS : MACRO-FEMTO COST STRUCTURE MODELLING

A. TCO : Total Cost of Ownership

The Total Cost of Ownership is a financial estimate to determine the direct and indirect costs of a product or a system over a certain time period. Cost comparisons based on current investment, or capital expenditure, have unfortunately been commonly used in marketing of new communication technologies.

For an operator, however, the total cost of ownership, (including both investments and running costs), in particular when comparing network sites with different cost structures, is more relevant, to assess the total business impact of a solution over its lifespan. So, rather than simply consider the initial price tag relative to a structure, MNO have to closely analyze the operational costs which are going to be incurred over the solution's intended lifespan. Basically, TCO is composed of three parts: First, the Capital Expenditures or CapEx, which in the case of network operators includes the cost of initial equipment purchase, as well as initial software investments, all related to the network deployment. Second, the Implementations Expenditures or ImpEx, including the site acquisition, the installation and the network planning costs. Those costs being incurred as an initial network investment costs for network operators, they are usually taken up under the CapEx category. The third category is the Operational Expenditures or OpEx, referred as the day-to-day ongoing costs for operating a product or a system. In our case, OpEx costs are related to recurring costs of network maintenance and service provisioning thus, could be divided into two cost categories: The network-related costs, such as network operating and maintenance, site rentals and transmission costs. And the non-network-related costs, such as customer care, administrative and billing.

In our study of cost analysis for heterogeneous macro-femto networks, only network-related costs are being considered, since "business driven" costs are

common to both networks and that our goal is to model the main relative differences and potential benefits in cost analysis when considering the deployment of heterogeneous macro-femto networks.

B. DCF : Discounted Cash Flow

The total cost of macro and femto sites within our TCO analysis is calculated based on the discounted cash flow model. The DCF is a standard economical valuation method to enable us evaluating the outgoing cash flow of a project, with an accurate cost model, where all discrete future cash flows are estimated and discounted to give their present values estimation. In our case, we use the DCF approach [2] in order to analyse the total cost structure of our heterogeneous network, taking into account both investments and operation costs. According to [2], in order to estimate the total cost of an element of type x , and give an estimation of its present value, we sum up the discounted annual total expenditures related to that item, representing all the future cash flows for the network investment, and for the whole network life cycle (K years), according to the following :

$$C_x = \sum_{n=0}^{K-1} \frac{C_x^{\text{CAPEX}} + C_x^{\text{OPEX}}}{(1+d)^n} \quad (1)$$

where C_x^{CAPEX} and C_x^{OPEX} are respectively the sum of annual capital and operational expenditures related to item x (either macro or femto site), achieved within K years of network life cycle, and d is the discount rate, also referred as weighted average cost of capital 'WACC' [3]. A discount rate of 8.9 % is assumed in this study, according to [4].

In our case, we only consider network-related costs. We also omit costs related to the mobile core network and service provisioning, since they are mainly independent of the radio access technology and infrastructure adopted.

C. Macrocell Cost Estimates

In order to estimate the total cost of a macro-cell structure, we will take into account the three parts composing the TCO: The CapEx part; including initial

TABLE 1. ESTIMATED CAPEX AND ANNUAL OPEX FOR MACRO SITE DEPLOYMENT

Component	Cost (k€)
CapEx	
BS Site& Equipement	100
Transmission Radio Equipment	20
TOTAL	120
OpEx	
Annual Site Lease	7
Annual Operation& Maintenance	7
Annual Power	4
Annual Backhaul Transmission	12
TOTAL	30

investments in BS and transmission equipment, site installation and deployment costs. The OpEx part; including operation and maintenance, site lease, power and backhaul transmission. As we stated before, the ImpEx, was included here within the CapEx costs, as part of initial investments. We performed our cost structure break down and modelling according to cost parameter assumptions based on comparison of empirical cost data investigated in [5]-[7] and obtained our main estimates for macro site cost structure. Table 1 outlines our main findings.

D. Femtocell Cost Estimates

Our estimations of femtocell cost structure is basically done the same way as macrocell one. Based on [6], the estimation of the initial investment for the deployment of a new femto site is on average of 1k€. The OpEx costs however are different from those of macrocell as they exclude site costs which are taken up by end users. Moreover, backhaul costs are also not included, as femto site is using the end users' broadband connection. This is mainly the same economic model which has been used for previous home-cell deployment strategies [8]. The annual operational costs estimates are around 0.5k€ per access point.

Our case study assumes that the femto site is fully subsidized by the network operator in order to fully take up the relative costs for the deployment of the femto service. This assumption is based on the fact that femtocell networks are expected to reduce the load of macrocell and are thus advantageous for operators (For example supporting new customers or save money in macrocell maintenance). Based on that, it is assumed that femtocells are fully paid and maintained by the network operator.

Table 2 outlines the results of estimated present value of each site category, based on Eq. (1), estimating the total costs of considered infrastructures, under our TCO approach.

III. INFRASTRUCTURE CAPACITY MODELLING AND COVERAGE SCENARIO

We consider a scenario where we need to provide cellular wireless data coverage for a newly built technopark of 1 km², composed of different companies, with an estimated 10 000 future workers. We will analyze the option of Macro eNodeB solution for service provisioning compared with femtocell indoor solution.

TABLE 2. ANNUALIZED CAPEX, OPEX AND TOTAL COST IN PRESENT VALUE PER SITE CATEGORY (COSTS IN [k€])

Site Category	Annual CapEx	Annual OpEx	Total Cost (Present Value)
Macrocell	12	30	294.82
Femtocell	0.1	0.5	4.21

A. Capacity Modelling

For a macrocell (a three sector site), the offered capacity is expressed as: $3 * SE * BW$, where SE refers to the system spectral efficiency and BW refers to the allocated bandwidth. In line with [6], where an average cell spectral efficiency between 0.5 – 2.0 bps per Hz is considered for an urban area and between 0.25 - 0.5 bps per Hz for a rural area, we will consider an average SE of 1.7 bps per Hz for the macrocell network. For the femtocell case; in line with [9], we consider an average spectral efficiency of 6.0 bps per Hz.

Based on those parameters, an LTE system with a three sector site and a 20 MHz allocated bandwidth will offers a capacity of around 100 Mbps. Concerning the femtocell with 5 MHz used spectrum, the total capacity offered by a single site would be around 30 Mbps.

B. User Demand

Based on [10], mobile traffic forecast studies performed by both Ericsson and Cisco are clearly showing that; “By 2019, mobile data traffic will be nearly six times 2014’s traffic”. In line with those projections of traffic growth within upcoming years, we consequently model the user demand, referred as the data usage (GB) per user and month. We consider two cases, corresponding to a moderate (35 GB) and high (50 GB) mobile generated traffic demand per user/ month. In our case, we consider a usage spread over 1 month and assumed 8 busy hours per day. For a moderate load of 35 GB, this would equal to 1.17 GB per day and 150 MB per busy hour. The conversion of this load to user data rates (Mbps) would equal to a user data rate of 0.33 Mbps per user. For the case of higher load of 50 GB per user and month, we would have user data rates corresponding to 0.46 Mbps per user.

IV. TCO RESULTS ANALYSIS

Having the total offered capacity per macro and femto site and users data rates, we would be able to determine the infrastructure to be deployed within our given scenario of 10,000 estimated future workers in a newly build technopark. Here, we consider a base case scenario where we assume network provisioning for indoor users based on only femto service or macro service, in order to assess the importance of relative cost difference between both technologies. In order to fairly compare between our estimated cost structures with different sites capacities, we use the key performance indicator (KPI) of normalized cost per MB/user/day.

Figure 1 shows us clearly the main differences in normalized costs of macro and femto sites, and that femto service has an absolute advantage due to both low generated costs and relative high offered capacity compared to the macro service. This figure also gives us important insights on the influence of each part composing our TCO, and as we can see, operational expenditures are

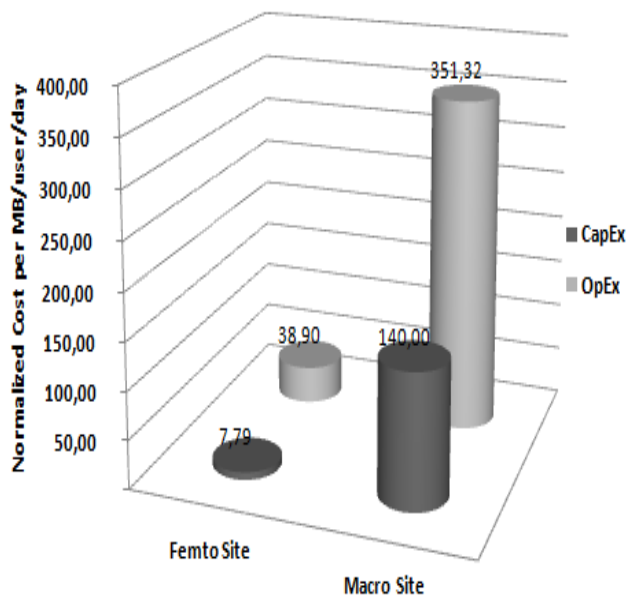


Figure 1. Femto and macro sites normalized costs per MB/user/day counting for almost 80% of total generated costs, since our approach for estimating the total cash flow of considered systems is being performed for the whole life cycle of a project (here estimated for 10 years).

Table 3 outlines the main findings related to the number of deployed macro and femto sites and the generated TCO for each infrastructure. We can here compare between the investment costs in TCO for separate network deployment, in the cases of high and moderate traffic loads. An important difference is noticeable between considered infrastructures, and this is basically expected regarding the shown difference in the normalized cost per offered capacity related to each service in our case. However, an interesting insight that has to be pointed out from those results is that femtocell is showing cost increase of the total structure up to 39%, between the moderate and high traffic demand cases, where, on the other hand, macrocell is showing total increased generated TCO up to 65%. Considering the projected traffic growth for the next few years, MNO should be aware of that important cost difference between structures, and especially in the case where more resources have to be deployed to meet those demand.

TABLE 3. TOTAL NUMBER OF MACRO AND FEMTO SITES AND RELATED TCO FOR EACH INFRASTRUCTURE

Traffic Load [User/Month]	Site Category	Number of Sites	Total Generated TCO [k€]
Moderate (35GB)	Femtocell	110	463.1
	Macrocell	23	6780.8
High (50GB)	Femtocell	153	644.1
	Macrocell	35	11203.2

V. CONCLUSION AND FUTURE WORK

In this paper, cost offloading benefits of femto deployment strategy are investigated. Cost estimation of network structures is made based on empirical data research and comparison, and the economical approach of Total Cost of Ownership is used in order to get an accurate cost model with up-to-date results. Our network capacity modelling and projected users' demand in line with traffic growth expectations has shown an absolute advantage for adopting this kind of offloading networks, within our cost approach. Besides, our results outlined the important difference of resulting network costs for both services, when considering the projected increase of future network traffic. However, this could be considered as a base case scenario, as MNO have to usually consider other deployment schemes rather than a single macro or femto provisioning approach. Based on those findings, extension of our work could be made in order to assess the offloading benefits of such structures based on joint provisioning case, or other specific deployment scenarios.

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Wafa Werda obtained her B.E. degree in computer networks and telecommunication engineering from the National Institute of Applied Science and Technology, Tunis, Tunisia, in 2013. She had a working experience as IT consultant within Ernest&Young advisory services, before joining Waseda University in April 2014 as a research student. She started her Master curriculum in October 2014 in the

Department of Communications and Computer Engineering. Her research field is mainly about economics and management of cellular networks. She is a member of IEICE.



Bo Gu received the B.E degree from Tianjin University, Tianjin, China, in 2004, M.E. degree from Peking University, Beijing, China, in 2007, and Ph.D. degree from Waseda University, Tokyo, Japan, in 2013, respectively. From 2007 to 2011, he was a research engineer at Sony Digital Network Applications, Japan. He is currently an assistant professor at Waseda University. His research interests include

resource and mobility management of wireless networks, QoS provisioning, and next generation wireless networks. He is a member of IEEE and IEICE.



Kyoko Yamori received her B.A. degree in business administration and M.A. and Ph.D. degrees in information management science from Asahi University in 1995, 1997, 2000. She is presently an associate professor at Department of Management, Asahi University, and a guest associate professor at Global Information and Telecommunication Institute, Waseda University. Her research

interests include network modeling and system-design, particularly inspired by economic and social aspects. She received the IEICE Switching System Research Award in 2001, the IEICE Young Researcher's Award in 2005, and the IEICE Best Paper Award in 2005, the Young Scientist Award from Ericsson Japan in 2007, respectively. She is a member of IEEE and a senior member of IEICE, Japan.



Yoshiaki Tanaka (B.E. 1974–M.E. 1976–Ph.D. 1979) received the B.E., M.E., and D.E. degrees in electrical engineering from the University of Tokyo, Tokyo, Japan, in 1974, 1976, and 1979, respectively. He became a staff at the Department of Electrical Engineering, the University of Tokyo, in 1979, and has been engaged in teaching and researching in the fields of telecommunication networks, switching systems, and network security. He was a guest professor at the

Department of Communication Systems, Lund Institute of Technology, Sweden, from 1986 to 1987. He was also a visiting researcher at the Institute for Posts and Telecommunications Policy, from 1988 to 1991, and at the Institute for Monetary and Economic Studies, Bank of Japan, from 1994 to 1996. He is presently a professor at Global Information and Telecommunication Institute, Waseda University, and a visiting professor at National Institute of Informatics. He received the IEEE Outstanding Student Award in 1977, the Niwa Memorial Prize in 1980, the IEICE Achievements Award in 1980, the Okawa Publication Prize in 1994, the TAF Telecom System Technology Award in 1995 and in 2006, the IEICE Information Network Research Award in 1996, in 2001, in 2004, and in 2006, the IEICE Communications Society Activity Testimonial in 1997 and in 1998, the IEICE Switching System Research Award in 2001, the IEICE Best Paper Award in 2005, the IEICE Network System Research Award in 2006 and in 2008, the IEICE Communications Society Activity Award in 2008, the Commendation by Minister for Internal Affairs and Communications in 2009, and the APNOMS Best Paper Award in 2009. Professor Tanaka is a Fellow of IEICE.