

# Impact of Self-Organizing Networks Deployment on Wireless Service Provider Businesses in China

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#### Abstract

Decoupling of revenues with network traffic and extreme penetration of expenses in wireless network leads to the critical situation for wireless service providers (WSP), as more wireless network is complex due to its heterogeneity in the context of planning, software & hardware installation, radio parameters setting, drive testing, optimization, healing and maintenance. These operations are time-consuming, labor & budget-intensive and error-prone if activated manually. Hence new approaches have to be designed and applied to meet those demands in a cost-effective way, Self-organizing networks (SON), is a promising approach to handle manual tasks with autonomous manners. More specifically the self-directed functions (self-planning, self-deployment, self-configuration, self-optimization and self-healing) are aid to reduce capital expenditure (CAPEX), implementation expenditure (IMPEX) and operational expenditure (OPEX). In this study, first we investigate the aforementioned impact factors of cost combined with self-functions. Then, we analyze the relative cost benefits causing from deploying the SON functions, using the economical method to have more precise results concerning those potential benefits. At last, the result shows that there is a significant difference in expenses and revenues of WSP with and without SON after enabling self-functions in wireless network.

#### **Keywords**

Wireless Service Providers, Self-Organizing Networks, Capital Expenditure, Operating Expenditure, Operating Revenues

## **1. Introduction**

Introducing the Long Term Evolution (LTE) wireless network promise with mobile operators to increase the revenue, a critical need is to reduce the network

expenses if operator wants to remain competent in the wireless world against Wi-Fi mesh network. Future wireless network is more complex due to its heterogeneity in the context of planning, software & hardware installation, radio parameters setting, deployment, configuration, drive testing, optimization, healing and maintenance. These operations are time-consuming, labour and budget-intensive for WSP and error-prone if activated manually. Due to these challenges, more efficient and smart network management way is urged to develop a system that deals these tasks with self-directed manners. In this context, SON is the surest way to manage the future wireless heterogeneous network with autonomous manners, low-cost and high margins [1] [2] [3].

The purpose of this study is to analyze the impact of SON deployment on WSP businesses in china and how we can reduce the cost and increase the total revenues with deployment of SON system model. The rest of this paper prepared as follows: In Section 2 overview of SON, Section 3 describes the methodology. Section 4 conducts the results and section 5 concludes the paper.

#### 2. Overview of SON

Ramiro *et al.* [4] and 3GPP [5] SON has been evolved as part of 3GPP standardization process with sub-functions: Self-configuration, Self-Optimization and Self-Healing. **Figure 1** Captures the SON three functions in release8/LTE networks [2] [14].

 3GPP (Rel. 9) [6] [7] [8]. Self-Configuration deals with the wireless network in an automated manner from basic setup of eNodeB to initial radio configuration. Under the umbrella of self-configuration, it can automate the configuration of IP address, detection of OAM & P, gate way (GW) setting, downloading of eNodeB software, neighbor list configuration, coverage and capacity of related parameters that minimize the human efforts and the cost efficient way for mobile operators to reduce the network expenses. Self-confi-



Figure 1. Self-organizing network.

guration also reduces the planning and deployment tasks.

- 3GPP (Rel. 13) [9]. Self-optimization brings with wireless network to utilize • the available resources in optimal way. Such as, mobility load balancing (MLB), inter-cell interference coordination (ICIC) [10], cell outage detection & compensation and energy consumption optimization. It can improve the coverage & capacity of the network and minimize the bundle of manual tasks particularly drive testing.
- 3GPP (Rel. 10) [11] [12] [13]. Self-healing mitigates the errors in an autonomous way by using the triggers or alarm. Self-healing first monitors the threats in the network then trace out the specific alarm, and after deep analysis it could be solved automatically. Self-healing function also improves quality of service (QoS) and quality of experiences (QoE).

## 3. Methodology

In methodology, we analyze the effects of SON in economic benefits of WSP by using the total cost of ownership (TCO) approach. TCO is a financial estimate to help the equipment vendors and buyers (WSP) determine the direct and indirect expenditures of equipments and quantify the financial impact on system over its certain life cycle. The data (all units in million RMB) were collected from three main China companies by their officially web through financial reports: China Mobile, China Unicom and China Telecom with respect to SON. This 15-year study is on China largest WSP that presented the economic benefits from the year (2010) when WSP enabled SON functionalities in LTE networks. We associate the objectives of WSP with technical functions and derive how SON will impact on three main contributors CAPEX, OPEX and Operating Revenue as a moderator.

#### 3.1. SON Impacted System Model for WSP

The SON X-Functions have directly impact on WSP business at the beginning of site planning as well as deployment and ongoing network operations.

Figure 2 indicates the impact of SON on WSP businesses in red shaded with high level grouping of activities. In this model, we capture the immediate benefits of SON in three parts: first, the CAPEX can be streamlined by pre-planning. Second, the implementation expenditures or IMPEX can be reduced in network deployment. Finally, OPEX is also a key factor which can be saved by optimization of network with SON.

- First phase (CAPEX) of wireless network begins from site design activities, in • which network planner pre-plan the number of activities. Activities are relevant to new location of eNodeB, pre-planning of radio & transport parameters, IP & interfaces management, CW & TI and data alignment. Self-configuration function automates these parameters, and it can automatically exchange all parameters information when the site power up. As specifically, neighbor list updating activity.
- Second phase (IMPEX) of wireless network starts from site acquisition &





Figure 2. System model from technical to finical benefits of SON.

physical installation of equipment and construction services (lease site, purchase equipment and softwares). These manual activities do not have any role of SON. In this phase, commission and integration of wireless network have a strong relationship with self-configuration and self-deployment. In commissioning and integration, normally engineers and technicians are attached with faulty or new cell site to configuring and integrating the installed equipments with core network. Self-configuration function promise with WSP to reduce such manual tasks in cost efficient way.

Third phase (OPEX) starts after deployment of wireless network. Now the
network is in operational state and related activates handover to OAM & P.
SON features such as cell outage detection and compensation, interference
mitigation & cancellation can minimize the drive testing in wireless network
which directly impact on WSP operational expenses. Additionally, the energy
optimize contributor also reduce the OPEX and save energy by switching off
unused parts of base stations in low traffic periods.

#### 3.2. Conceptual Framework

In **Figure 3** Conceptual framework OPEX cost could be divided into two sections: The network-related cost such as, transmission line cost, interconnection cost, other network maintenance cost. And the non-network-related costs, such as depreciation expense, personal expense, selling expense and cost of product sold expense. In our work of cost analysis for WSP, only network-related cost



Figure 3. Conceptual framework for WSP Businesses.

i being focused. The network-related impactors such as (Interconnection expense, leased line transmission expense and other operational & maintenance expense) have a great impact on OPEX, and our motive is to model the main relative differences in cost analysis when considering the deployment of SON in wireless network. Furthermore, SON functions which have deployed in wireless network can reduce the operation cost and can increase the operating revenue from both CAPEX and OPEX as shown in **Figure 2**.

#### 3.3. Hypothesis

- H1: There is a significant difference between CAPEX and SON.
- H2: There is a significant difference between OPEX and SON.
- H3: There is a significant effect of CAPEX on operating revenue among SON.
- H4: There is a significant effect of OPEX on operating revenue among SON.

**Figure 4** captures the graphical representation of the operating revenues, EBITDA, N.P and EPS of WSP among SON. And the results show that the performance with SON is better than without SON.

#### 4. Experimental Results and Discussion

**Table 1** explains the benefits of SON on average operating revenue, average earnings before interest taxes depreciation amortization (EBITDA), average net profit (N.P) and average earning per share (EPS). Also it shows that averages of revenues, EBITDA, N.P and EPS of WSP business with SON are better than without SON.

**Table 2** shows the benefits of SON on CAPEX, leased transmission line expense, interconnection expense, depreciation expense, personal expense, selling expense, and cost of product sold expense and other expenses. It indicates that expenses of WSP business with SON are better than without SON.

**Table 3** indicates independent sample means the test of operating revenue, EBITDA, net profit and EPS with and without SON. The P value of Levene's test



Without SON With SON

Figure 4. Benefits of SON on WSP businesses.

Table 1. Distribution of revenues for WSP among SON.

Case	Operating revenue x±S	EBITDA x±S	Net Profit x±S	EPS x±S
Without	164598.10	75400	28300	1.2534
SON	±103286.748	±60710	±30710	±1.59496
With SON	364617.60	136000	48400	2.1792
	±161964.884	±80050	±53580	±2.81957

Table 2. Distribution	of expenses for	WSP among SON.
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Case	CAPEX	Leased Transmissi on Line	Interconnecti on Expenses	Depreciation Expenses	Personal Expenses	Selling Expenses	Cost of Product Sold	Other Expenses
	$\bar{\mathbf{x}} \pm \mathbf{S}$	⊼±S	⊼±S	⊼±S	⊼±S	⊼±S	⊼±S	<b>x</b> ±S
Without	48700	4311.00	18098.27	39500	13430.00	11444.83	919.20	33478.73
SON	±30530	±5733.209	±10784.797	±20320	±9262.572	±10815.743	±1475.039	±47410
With	91800	14580.47	32780.53	74000	34644.13	59543.60	14152.87	65930.93
SON	±35880	±14481.174	±19162.520	±21770	±8278.674	±24095.618	±24335.489	±58230

is 0.006 < 0.05 for operating revenue with and without SON is significant. Therefore, we assume population variances are not equal assumed of operating revenues. Then the value of test statistics is T = 4.360 and P = 0.01 < 0.05. It means there is a significant difference between operating revenue with and without SON. The P value of Levene's test is 0.025 < 0.05 for EBITDA with and without SON is significant. Therefore, we assume population variances are not equal assumed of EBITDA. Then the value of test statistics is T = 2.576 and P = 0.01 < 0.05. It means there is significant difference between EBITDA with and without SON. Even in all remaining cases like N.P and EPS are significant for with SON and without SON.

**Table 4** indicates independent sample means test of capital expenditure CAPEX, leased line expense, interconnection expense, depreciation expense, personal expense, selling expense, cost of product sold and other expense with

	Indepe	endent Sampl	es Means Tes	st		
		Levene's Test for Equality of Variances		t-test	of Means	
		F	Sig.	Т	D.F.	Sig. (2- tailed)
Operating Revenue	Equal variances assumed	8.343	.006	5.042	43	.000
	Equal variances not assumed			4.360	19.876	.001
EBITDA	Equal variances	5.413	.025	2.825	43	.007
	assumed Equal variances not assumed			2.576	22.320	.017
Net Profit	Equal variances assumed	17.046	.000	1.600	43	.037
	Equal variances not assumed			1.343	18.733	.032
EPS	Equal variances assumed Equal variances not	18.183	.000	1.411 1.181	43 18.608	.021 .025
	assumed					

#### **Table 3.** Independent samples means test of revenues of WSP among SON.

**Table 4.** Independent samples means test of WSP Expenses among SON.

	Indepe	endent Sampl	es Means Te	st		
		Levene's Equality of	Test for Variances	t-test 1	for Equality	of Means
		F	Sig.	Т	D.F.	Sig. (2- tailed)
CAPEX	Equal variances	.994	.324	4.208	43	.000
	Equal variances not assumed			3.984	24.424	.001
Leased Line Expense	Equal variances	40.456	.000	3.415	43	.001
	Equal variances not assumed			2.645	16.232	.017
Interconnection	Equal variances	12.517	.001	3.300	43	.002
	Equal variances not assumed			2.757	18.561	.013
Depreciation Expense	Equal variances	.036	.851	5.233	43	.000
	Equal variances not assumed			5.112	26.434	.000
Personal Expense	Equal variances	1.132	.293	7.492	43	.000
	Equal variances not assumed			7.783	31.124	.000
Selling Expense	Equal variances	22.350	.000	9.292	43	.000
	Equal variances not assumed			7.369	16.880	.000
Cost of Product Sold	Equal variances	34.844	.000	3.002	43	.004
	assumed Equal variances not assumed			2.104	14.051	.054
Other Expense	Equal variances	2.595	.115	2.005	43	.051
	Equal variances not assumed			1.871	23.570	.041

and without SON. The P value of Levene's test is 0.324 < 0.05 for CAPEX with and without SON is insignificant. Therefore we assume population variances are equal assumed of CAPEX. Then the value of test statistics is T = 4.208 and P = 0.01 < 0.05. It means there is significant difference between CAPEX with and without SON. The P value of Levene's test is 0.001 < 0.05 for leased line expense with and without SON is significant. Therefor we assume population variances are not equal assumed of leased line expenses. Then the value of test statistics is T = 2.645 and P = 0.01 < 0.01. It means there is significant difference between leased line expense with and without SON. Even in all remaining cases like interconnection expense, depreciation expense, personal expense, selling expense, cost of product sold expense and other expense are significant for without SON and with SON.

**Table 5** shows the multiple linear regression model summaries. It has found that adjusted R square of this model is 0.990, with R square equals to 0.992 that means 99.2 information explained of dependent variable (Operating Revenue) through all independent variables and the standard error of the estimate is 10531.073 the Durbin Watson D = 2.3 which is between the two critical values of 1.5 < D < 2.5 and therefore we can assume that there is no first order linear autocorrelation in our multiple linear regression data.

**Table 6** Analysis of variance (ANOVA) shows the overall model is significant. The P value of our model is 0.001 < 0.05 therefore overall model is significant for WSP.

**Table 7** shows the individual comparison of independent variables with dependent variable. The value of beta is equal to 0.265 showing the positive relationship between CAPEX and Operating Revenue which means that when CAPEX increases, Operating Revenue will also increase. Also the p value of CAPEX is 0.001 which is < 0.05 means that there is significant effect of CAPEX on Operating Revenue. The value of beta is equal to 2.075 showing the positive relationship between Leased line expenses and Operating Revenue it means that when the Leased line expenses increase, Operating revenue will also increase.

Tab	le 5.	Model	summary	of	operating	revenue	of	WSP	withou	t SO	N.
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Model Summary									
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin Watson				
1	.996*	.992	.990	10531.073	2.3				

Table 6. Analysis of variance of operating revenue of WSP without SON.

Model	Sum of Squares	Df	Mean Square	F	Sig.
Regression	3.070E11	8	3.838E10	346.075	.001
Residual	2.329E9	21	1.109E8		
Total	3.094E11	29			

Model	Unstandardized Coefficients		Т	Sig.	Colline Statist	arity ics
	В	Std. Error			Tolerance	VIF
(Constant)	7043.575	8591.296	.820	.422		
CAPEX	0.265	.137	6.304	.000	.218	4.592
Leased Line	2.075	.554	1.943	.046	.380	2.633
Exp						
Interconnecti- on Exp	1.67	.612	3.040	.006	.1	7.321
Dep.Exp	1.30	.392	3.215	.004	.120	8.34
Personal Exp	3.37	.730	3.130	.005	.131	9.442
Selling Exp	1.952	.670	2.913	.008	.121	8.275
Cost of	2.651	3.535	1.033	.031	.141	7.109
Product Sold						
Other Exp	3.404	.119	12.098	.001	.120	8.344

Table 7. Coefficients of operating revenue without SON.

The p value of Leased line expenses is 0.04 which is <0.05 means that there is significant effect of Leased line expenses on Operating Revenue. We see that in all remaining cases of expenses there is positive relationship between expenses and operating revenue. The P-Value for all cases is <5 percent. Its mean there is significant relationship between operating revenue and expenses. This table also analyzes multi-Collinearity in multiple linear regression models. Tolerance should be greater than 0.1 or VIF < 10 for all variables which they are. Therefore there is no multi-Collinearity among the variables.

Table 8 shows the multiple linear regression model summaries. It has found that the adjusted R square of this model is 0.993, with R square equals to 0.997 that means 99.7% information explained of dependent variable (Operating Revenue) through all independent variables and the standard error of the estimate is 13850.867 the Durbin Watson D = 2.5 which is between the two critical values of 1.5 < D < 2.5 and we can assume that there is no first order linear autocorrelation in our multiple linear regression data.

Table 9 Analysis of variance (ANOVA) shows the overall model is significant. The P value of our model is 0.001 < 0.05 therefore there is a significant effect on dependent variable through all independent variables.

Table 10 shows the individual comparison of independent variables with dependent variable. The value of beta is equal to 1.43 showing the positive relationship between CAPEX and Operating Revenue it means that when CAPEX increases, Operating Revenue will also increase. The p value of CAPEX is 0.03 which is <0.05 means that there is significant effect of CAPEX on Operating Revenue. The value of beta is equal to 4.123 showing the positive relationship between Leased line expenses and Operating Revenue which means that when the Leased line expenses increase, Operating revenue will also increase. Also the p value of leased line expenses is 0.051 which is <0.05. It means that there is significant effect of leased line expenses on operating revenue. We see that in all remaining cases of expenses there is positive relationship between expenses and



Table 8. Model summary of operating revenue with SON.

Model Summary									
Model	R	R Square	Adjusted R	Std. Error of	Durbin				
		Square	the Estimate	Watson					
1	.998*	.997	.993	13850.867	2.5				

#### Table 9. Analysis of variance of operating revenue with SON.

Model	Sum of Squares	Df	Mean Square	F	Sig.
Regression	3.661E11	8	4.576E10	238.541	0.001
-					
Residual	1.151E9	6	1.918E8		
Total	3.673E11	14			

#### Table 10. Coefficients of operating revenue with SON.

Mode1	Unstandardized Coefficients		Т	Sig.	Colline Statis	earity tics
	В	Std. Error			Tolerance	VIF
(Constant)	-189756.769	92115.566	2.060	.085		
CAPEX	1.43	.189	1.220	.036	.120	8.337
Leased Line Exp	4.123	1.310	2.433	.051	.121	6.134
Interconnection Exp	6.550	2.681	2.443	.050	.103	8.16
Dep.Exp	5.930	1.949	3.043	.023	.103	9.313
Personal Exp	8.856	3.499	2.531	.045	.113	6.239
Selling Exp	6.392	.863	2.770	.032	.214	7.561
Cost of Product Sold	3.054	.763	1.228	.046	.303	9.001
Other Exp	3.520	.883	.223	.054	.201	8.998

operating revenue and the P-Values for all cases is less than 5 percent. It means there is significant relationship between revenues and expenses. This figure also analyzes multi-Collinearity in multiple linear regression models. Tolerance should be greater than 0.1 or VIF < 10 for all variables which they are. Therefore there is no multi-Collinearity among the variables.

#### Before and after Saving through SON

In case of without SON (**Table 7**) the value of CAPEX  $\beta_{without\_son} = 0.265$  hence there is positive relationship between CAPEX and operating revenue. It's mean if one unit of change in CAPEX then increase in operating revenue is 0.265 unit. In case of with SON (**Table 10**) the value of CAPEX  $\beta_{with\_son} = 1.43$  also there is positive relationship between CAPEX and operating revenue. It means one unit of change in CAPEX then increase in operating revenue is 1.43 unit. Results shows that operating revenues with SON more than without SON. We see that CAPEX  $\beta_{without\_son}(0.265) < \beta_{with\_son}(1.43)$ , Leased line expense  $\beta_{without\_son}(2.075) < \beta_{with\_son}(4.123)$ , Interconnection expense  $\beta_{without\_son}(1.67) < \beta_{with\_son}(6.550)$ , Depreciation expense  $\beta_{without\_son}(1.03) < \beta_{with\_son}(5.930)$ , Personal expense  $\beta_{without\_son}(6.392)$ , Cost of product sold  $\beta_{\text{without_son}}$  (2.651) <  $\beta_{\text{with_son}}$  (3.054) and Other expense  $\beta_{\text{without_son}}$  $(3.404) < \beta_{\text{with son}}(3.520)$ . It is clear that in case of with SON operating revenue will increase than without SON operating revenue. The immediate benefits of SON show the high margins for WSP through saving of CAPEX and OPEX.

#### **5.** Conclusion

In this study, we have examined the impact of SON deployment on WSP businesses in terms of lower OPEX and streamlined CAPEX, with and without SON, and we also proposed the conceptual framework where we showed that business benefits of SON are measurable in LTE network. This 15-year study is on China largest WSP and it shows that economic benefits are obtained from the year when WSP enabled the SON functions in LTE wireless network. After applying the SON functions in LTE wireless network, the WSP operating revenue, EBITDA, N.P and EPS are more than without SON. And the result shows that there is significant difference in expenses and revenues with and without SON. In this work, calculations are indicative because SON functions are not fully mature in wireless network. The future research on SON can involve automatic small cells management, due to its complex nature in next generation mobile network (NGMN).

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