Dimensioning and Cost Structure Analysis

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1. Introduction

This task is called dimensioning and cost structure analysis of wireless network, which is to dimension and design a radio access network and analyze the cost structure for different deployment options and types of used Radio Access Technologies (RATs). The specific case is described by the following table and All the calculation and analysis are done under these requirements in table 1:

Tab.1 Dimension requirements

Type of user and BB usage	Type of Operator	Type of Area	RATs to Analyze
Complement1	Incumbent	Urban	HSPA Macro/LTE Micro/LTE Pico/femto

2. Notations

Since the type of area is urban, the density of users is $D = 1000\, users / km^2$

Since the type of user and BB usage is complement1, we can get the penetration and the data usage per user from formula 1 and 2.

$$P_x = [P_1\ P_2\ P_3\ P_4\ P_5] = [0.1\ 0.2\ 0.3\ 0.4\ 0.5] \tag{1}$$

$$U_x = [\mathrm{U}_1\ U_2\ U_3\ U_4\ U_5] = [6\ 7\ 8\ 9\ 10]\,(\mathrm{GB/\ month}) \tag{2}$$

P_x represents the penetration for year x and U_x is the usage per user for year x.

Ase represents the Average spectral efficiency for a type of RAT deployment, W is the bandwidth for a type of RAT deployment. Since from table 1, the type of operator in this case is Incumbent, the bandwidth of the RATs can be known $W_{HSPA} = 5MHz$ and $W_{LTE} = 20MHz$. $R_{\max}$ means the maximum cell range of a typical RAT.

In this case, S_x represents the area need to be coveraged for year x. By using the coverage rate which was given, and we know that the the urban area is 1000 km^2, formula 3 will show the coverage area for year x.

$$S_x = [S_1\ S_2\ S_3\ S_4\ S_5] = [200\ 400\ 600\ 800\ 1000](km^2) \tag{3}$$

3. User Demand

The first analysis step is to calculate the user demand in urban area for years 1-5. In this case, since the traffic is assumed to be concentrated to 4 hours per day, we can the total surfing time for one month is $T = 4 \times 30 \times 60 \times 60 = 432000s$. The user demand can be described by formula 4:

$$UserDemand_x = \frac{D \times P_x \times U_x}{T} \tag{4}$$

In formula 4, $UserDemand_x$ represents the user demand for year x. The results can be shown is table 2.

Tab.2 User demand from year 1 to year 5

	Year 1	Year 2	Year 3	Year 4	Year 5
UserDemand ($Mbps / km^2$)	11.11	25.93	44.44	66.67	92.59

4. Model the Radio Access Technologies

In this section, the task is to model the RAT's in terms of coverage, capacity and cost. Requirements for the deployment are described in terms of coverage and capacity.
The capacity (Mbps per area unit) is to be calculated using estimates of average data usage per user and the number of users. In this case, formula 5 can represent the capacity. Formula 6 is used to calculate the coverage of a cell.

$$Cap = Ase \times W \tag{5}$$

$$Coverage_{cell} = \tfrac{3\sqrt{3}}{2} R_{\max}{}^{2} \tag{6}$$

Table 3 shows the results of both coverage and capacity of the RAT, according to the formula 5 and 6.

Tab.3 Coverage and capacity of different RATs

Deployment	$Ase(bps / Hz)$	W	$Coverage_{cell}(km^2)$	$Cap(Mbps)$
HSPA Micro	1.00	5MHz	0.648	5
LTE Micro	2.00	20MHz	0.104	40
LTE Pico/femto	2.00	20MHz	0.026	40

We can compare the results of the RATs' capacities from table 3 and the user demands from table 2.

To get the number of site needed to be deployed, we should consider both the capacity and the coverage, and then compare the results to choose the site's number.
Formula 7 represents the sites' number which related to the capacity and user demand:

$$N = \frac{Userdemand_x \times S_x}{Cap} \tag{7}$$

It is easy to know when $x = 5$ the number of sites will be the max. Table 4 will show the number of sites according to the user demands and RAT's capacity for differents sites (all the site numbers are rounded up).

Tab.4 Number of sites according to the user demands and RAT's capacity

Deployment \ Year x	1	2	3	4	5
HSPA Micro	445	2075	5334	10667	18519
LTE Micro	56	260	667	1334	2315
LTE Pico/femto	56	260	667	1334	2315

Formula 8 represents the sites' number which related to the coverage for year x:

$$N_x = \frac{S_x}{Coverage_{cell}} \tag{8}$$

By applying formula 8 into consideration, we can calculate the number of sites according to the coverage. Table 5 will show the result:

Tab.5 Number of sites according to the coverage

Deployment \ Year x	1	2	3	4	5
HSPA Micro	308	616	924	1231	1539
LTE Micro	1924	3847	5770	7693	9616
LTE Pico/femto	7963	15385	23077	30770	38462

It is necessary to fulfill the coverage and user demand at the same time, we need to compare table 4 and table 5 to find the max number of the site. In this case, by comparing the data in Tab.4 and Tab.5, we can get the final result of the site's number in table 6:

Tab.6 Number of sites by considering both coverage and capacity

Deployment \ Year x	1	2	3	4	5
HSPA Micro	445	2075	5334	10667	18519
LTE Micro	1924	3847	5770	7693	9616
LTE Pico/femto	7963	15385	23077	30770	38462

5. Capital Expense(CAPEX)

This part is to calculate the CAPEX, the price erosion of all equipment is assumed to be $PE = 5\%$ and the discount rate for Net Present Value calculation is 10%. Firstly we need to integrate all costs for CAPEX into table 7:

Tab.7 The cost for each depolyment(kEuro)(CAPEX)

Deployment \ Cost	Equipment	Installation	Deployment	Transmission	Sum
HSPA Micro	2	10	20	10	42
LTE Micro	4	10	20	10	44
LTE Pico/femto	1	2		0	3

Formula 9 shows how to calculate the CAPEX:

$$CAPEX = \begin{cases} N_x \times Cost & x = 1 \\ (N_x - N_{x-1}) \times Cost - Cost_{equipment} \times \sum_{i=1}^{x} (N_i - N_{i-1}) \times (1 - PE)^{x-i+1} & x > 1 \end{cases} \quad (9)$$

In formula 9, $Cost$ is the sum for each deployment, $Cost_{\text{equipment}}$ represents the cost produced by the equipment. The site's number is got from table 6. Table 8 shows the results of CAPEX and Figure 1 shows the CAPEX results for each deployment according to formula 9:

Tab.8 CAPEX results

Deploy \ CAPEX (kEuro) \ Year	1	2	3	4	5	sum
HSPA Micro	18690	68295	136540	223435	328971	775936
LTE Micro	84656	84208	84207	84207	84206	421486
LTE Pico/femto	23889	21857	22672	22674	22671	113781

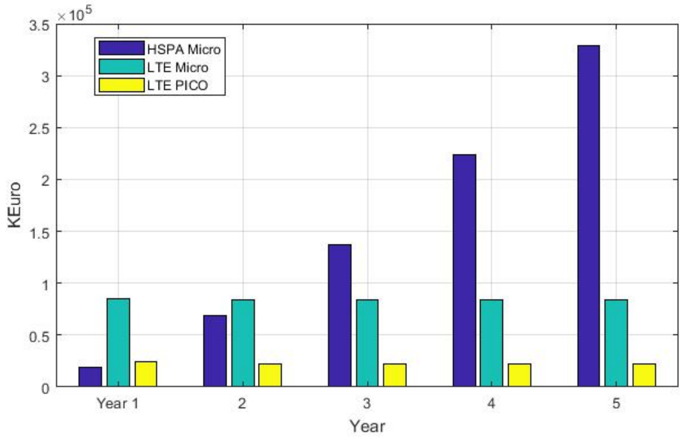

Fig.1 The comparison of CAPEX among HSPA Micro/LTE Micro/LTE Pico for different year

The results show that both LTE Micro and LTE Pico/femto have few fluctuations since all these two RAT site's number are decided by the coverage, and the difference in annual coverage area is the same, with small equipment cost and constant equipment erosion $PE = 5\%$, Indeed, CAPEX should not change much every year for these two RATs.
However, when it comes to the HSPA Micro, we can find that it has the lowest CAPEX at first year and grow rapidly to be far more CAPEX than the other two. The reason is that HSPA Micro site's number was decided by the user demand, which increasing rapidly to cause this result.

6. Operating Expense(OPEX)

An operating expense (OPEX) is an ongoing cost for running a product, business, or system which should be considered into this task two. Firstly we need to integrate all costs for OPEX into table 9, the operation and maintenance cost can be calculated from 10% of CAPEX.

Tab.9 The cost for each depolyment(kEuro)(OPEX)

Cost(kEuro) / Deployment	lease	transmission	electricity	operation	Sum(except operation)
HSPA Micro	4	1	1	0.1*CAPEX	6
LTE Micro	4	1	1	0.1*CAPEX	6
LTE Pico/femto	1	1	0.1	0.1*CAPEX	2.2

By concluding the methods of how to calculate OPEX, we can get formula 10 to represent OPEX for each year. In formula 10, SUM_{no_op} represents the anual OPEX except the operation and maintenance cost . x is the year.

$$OPEX_x = N_x \times SUM_{no\_op} + CAPEX_x \times 10\% \qquad (10)$$

After calculate the OPEX by using formula 10, we can get the result in table 10:

Tab.10 OPEX results

OPEX (kEuro) / Year / Deploy	1	2	3	4	5	sum
HSPA Micro	4539	14319	33873	65871	112983	231585
LTE Micro	20009	31547	43085	54623	66161	215428
LTE Pico/femto	19907	36235	53158	70082	87005	266390

The comparison of the OPEX results is shown in figure 2:

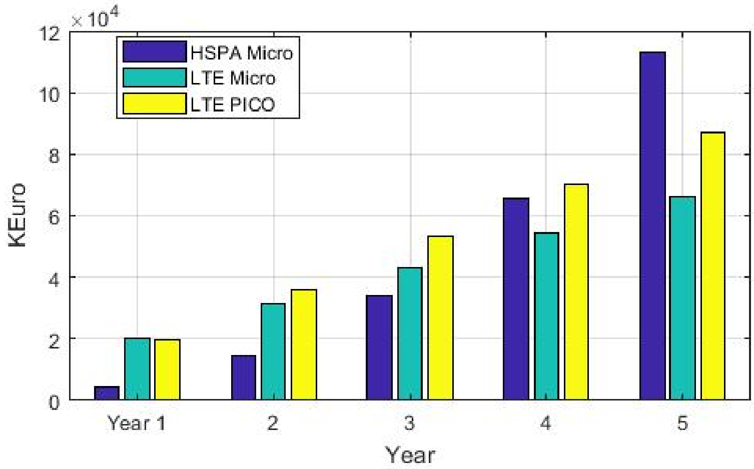

Fig.2 The comparison of OPEX among HSPA Micro/LTE Micro/LTE Pico for different year

To fully explore the costs, it is necessary to calculate the total cost which is the sum of OPEX and CAPEX. Figure 3 shows the results of the total cost:

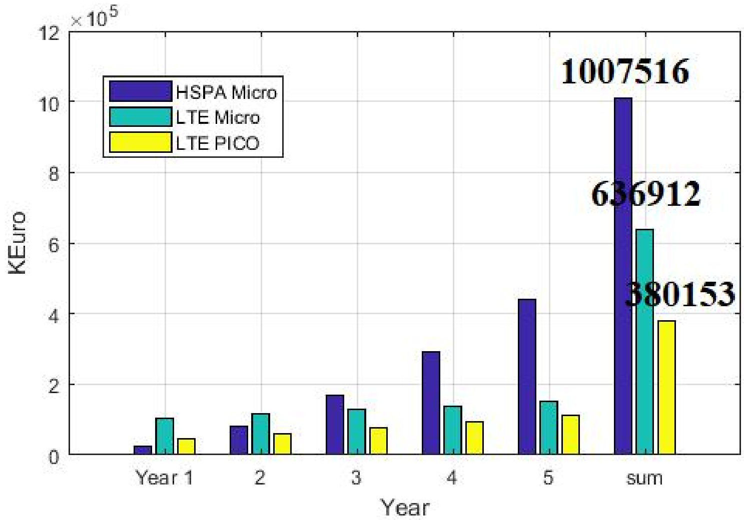

Fig.3 The comparison of total cost among HSPA Micro/LTE Micro/LTE Pico for different year

From figure 3 we can find HSPA Micro costs the most, LTE Micro is the second, LTE Pico/femto costs the least.

In finance, the net present value is a measurement of profit calculated by subtracting the present valuesof cash outflows from the present values of cash inflows over a period of time. Formula 11 is the presentation of NPV:

$$NPV = \qquad (8)(unsolved)$$

6. Conclusion

From the results(figure 1, 2 and 3) , it is easy to find that LTE Pico/femto is the better choice when the scenery comes to table 1.

7. Appendix

All the code used to program the calculation was operated in MATLAB, the codes are updated in my github, the reader can check them, now they are open sources.

For CAPEX: https://github.com/NymeriaWang/IK2514HW3/blob/master/HW3_CAPEX.m

For OPEX: https://github.com/NymeriaWang/IK2514HW3/blob/master/HW3_OPEX.m