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A Techno-Economic Analysis of Employing a central Coordinator Entity in 5G Networks

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Abstract. This research work describes the role of the Central Controller and Coordinator (C3) entity and its potential techno-economic gain when implemented in the upcoming 5G networks. We investigate how viable could be for a C3 Producer and for a cellular network Operator to produce and implement respectively the C3 entity in its network. The performance of techno-economic analysis is estimated by considering various key parameters and some useful conclusions are drawn.

Keywords: 5G, C3 entity, techno-economic analysis, producer, operator.

1 Introduction

"Mobile data traffic will grow at a compound annual growth rate (CAGR) of 47 percent from 2016 to 2021", according to [1]. So mobile network operators are facing massive data growth, but their revenues are usually not following this trend directly. This means that the operators need to provide the required capacity in a more efficient way. Moreover, mobile operators need to re-evaluate their network architecture due to advanced requirements of various applications. So it is crucial to identify the most flexible and cost-effective infrastructure model for next-generation services. In particular, the new mobile network needs to provide capacity exactly when and where it is required. Another challenge is that despite the fact that LTE and next generations of mobile networks offer lower price per bit, operators cannot switch off their legacy 2G / 3G networks. Thus operational costs need to be optimized by outsourcing or by shared operations.

There are also high expectations for new markets toward which the 5G technology is evolving [2, 3]. These markets are associated with Machine-to-Machine (M2M) type

communication and Ultra-Reliable Communication (URLLC), but they are not yet well understood by operators. Therefore, flexibility of configuration and operation are probably the most profound features expected from future 5G networks in order to provide these new types of services. A new sharable architecture is needed which should be flexible and easily manageable to satisfy the needs of the end users. The network controller and its clients at the Radio Access Network (RAN) level have to be highly adjustable to accommodate changing traffic characteristics such as bandwidth and latency requirements.

The COHERENT project [4] focuses on developing a next generation unified programmable control and coordination framework for various heterogeneous radio access networks, with demonstrators based on LTE and Wi-Fi. It adopts the concept of resource and service virtualization across technology domains. The COHERENT architecture includes the C3 entity that exploits the software-defined networking (SDN) and virtualization concepts [5-7], and converts the existing wireless mobile networks to contemporary, flexible, scalable, efficient and interoperable 5G networks.

The main contribution of our research work is the techno-economic analysis of employing the C3 entity in the 5G networks that highlights the potential financial gain value from two different perspectives, namely of the C3 producer and of the cellular network Operator.

In this research work, we perform a techno-economic analysis of how employing the C3 entity in 5G networks could provide profit for producer and operator companies. In Section 2, the C3 entity and the architecture, where it is integrated, are indicated, whereas in Section 3, a detailed techno-economic analysis is performed from two different business perspectives. Finally, in Section 4, the results of this techno-economic analysis are presented, while interesting conclusions are drawn in Section 5.

2 COHERENT Architecture and C3 Entity

The COHERENT architecture [8] provides a programmable control and coordination that offers fine grain, real-time control. Scalability and timeliness for control and coordination are achieved by introducing two control mechanisms, namely Central Controller and Coordinator (C3) and Real-Time Controller (RTC), as shown in Fig. 1. By receiving status reports from low layer entities, C3 maintains a centralised network view of the governed entities, e.g., transport nodes (TNs) and Radio Transceivers (RTs) in the RAN. For example, an RT could be a legacy LTE eNodeB or a legacy WiFi Access Point (AP) or a New Radio Base Station (NR BS).

Based on the Centralised Network View (CNV), the SDN principles are applied in the design of the C3. For overcoming the delay limitation between the C3 and the individual access network elements, latency-sensitive control functionalities are offloaded from the C3 to RTCs. The network entities connect to C3 and RTCs through the southbound interface (SBi).

As mentioned before, C3 is a logically centralised control entity because the C3 instances share the network graphs with each other. The communication between controllers (RTC-C3, C3-C3) for sharing network graphs and offloading control functions is through east-west interface (EWi).

The service plane is defined as a collection of specific network applications and Radio Access Technology (RAT) configurations. Different network slices contain different network applications and configuration settings as shown in Fig. 1. Through northbound interface (NBi), the C3 and/or RTCs provide the required network view, namely slice-specific network view (SNV), for the network service slices so that network service slices could express desired network behaviours (by programming) without being responsible themselves for implementing that behaviour (with hardware).

Some application modules in network slices may be latency-sensitive. For such a slice, these modules are located in the RTC. Additionally, monitoring modules which are latency-sensitive may need to operate close to the data source for reducing overhead and observe the network at high information granularity. The need for such monitoring modules may be service specific or operation specific. The examples of latency-sensitive network applications are flexible RAN function splitting in Cloud- RAN, MAC scheduling, handover decision, cell reconfiguration. In addition, most of the Mobile Edge Computing application areas [9] are also relevant to RTC, e.g., localisation, augmented reality, low latency IP service, etc. In general, we could have different views inside the same slice, according to what the application wants to do.

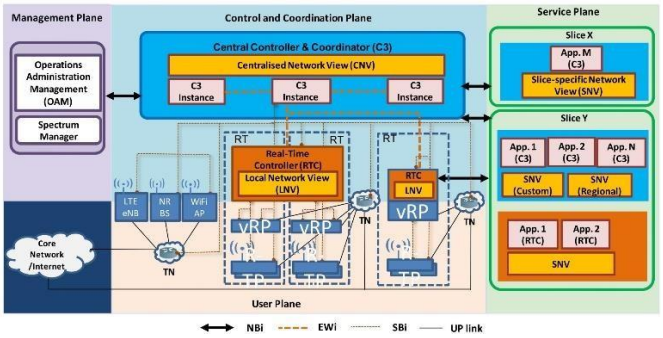


Fig. 1. COHERENT Architecture [8].

While the COHERENT control and coordination plane makes control decisions for RAN functions and sends the decisions to the network entities for executing the decisions, the management plane usually focuses on monitoring, configuring and maintaining the long-term decisions for network entities in the infrastructure, e.g., queries the databases managed by the National Regulation Agency (NRA) for the spectrum usage rules in the spectrum manager [10]. The entities in management plane are connected to the C3 through NBi.

3 Techno-economic Analysis

This section presents a detailed financial analysis of employing the C3 entity from two different business actors' point of view [11]:

I. C3 Producer's point of view
II. Operator's point of view

3.1 Financial Model

A key step in the process of planning a transition path towards COHERENT network deployment is the evaluation of the network economics. Specifically, C3 producers and network operators should consider choosing the evolution path that yields the most economic value, including revenues, capital expenditures (CapEx) and operating expenditures (OpEx) over the economic life of the system. Note that economic evaluation may have to be based on assumptions about the evolution of demand and service penetration.

To implement a financial model where all of the described aspects are properly taken into account, specially designed tools are normally used. This implies a sequence of steps to go through to associate values to the input parameters. Running the model generates the technical and financial outputs driven by geographical data, service demand and network costs.

Furthermore, the main financial parameter that reflects the success of an investment is the ***Net Present Value (NPV)***. The NPV of an investment is the present (discounted) value of future cash inflows minus the present value of the investment and any associated future cash outflows. NPV is important because it gives more accurate solutions in the out years. This metric recognizes that money has different real value over time and makes the values of money constant by discounting costs and benefits over a specific period of time—an asset's life cycle or any selected period of analysis. On a less formal level, this metric can be indicative of the profitability of a business over the years. Given the (period, cash flow) pairs (t, R_t) where N is the total number of periods, the NPV is given by:

$$NPV\ (i,N) = \sum_{t=0}^{N} \frac{R_t}{(1+i)^t}$$

where, ***t*** – the time of the cash flow; cash flow equals to the revenues minus the costs.

i – the rate of return WACC; the opportunity cost of capital.

Rt – the cash flow at time t.

Finally, there is one more input parameter that is needed, namely the ***Weighted Average Cost of Capital (WACC)*** of the company for this investment. The WACC is the average rate of return that the company expects to compensate all its different investors. The weights are the fraction of each financing source in the company's target capital structure. The WACC can serve as a useful reality check for investors. In this analysis, the WACC for the C3 Producer and Operator Company is 10%.

3.2 C3 Producer

This subsection describes a techno-economic analysis of employing the COHERENT architecture and specifically the C3 entity from the C3 Producer's point of view.

The viability of the C3 Producer (i.e. Start-up Company) is going to be evaluated over a period of seven years. The C3 Producer is going to invest on this architecture (i.e. developing the product and selling its services to multiple operators) because it would like to gain some revenues. The results of this analysis will show the economic benefits of employing the COHERENT architecture from the C3 Producer's point of view. The costs and revenues of the C3 Producer are categorized into the following general groups, as shown in Table 1.

More specifically, each group is further explained below, after making the necessary realistic assumptions for business related works with similar cost-revenues methodology [12]:

I. ***Cost of business***—includes the sum of the personnel-related cost, i.e. head count (15-25) and cost per employee (80 k€ - 84 k€), the fixed assets (10 k€ - 50 k€), the production cost (60 k€ - 150 k€) and the marketing cost (50 k€ - 100 k€), according to the COHERENT original approach. It is also taken into consideration a company overhead factor (e.g. accounting, depreciation, insurance, license fees, taxes, rent), which is usually 0,3-0,5.

The approach is that there is a basic functionality, such as mobility and load balancing, which can be enhanced by additional features. For each additional feature the producer revenue is defined as percentage of the infrastructure served by one C3 and a penetration factor. The producer will have revenues on both C3 and agents:

II. ***Basic SW C3 + agent revenues***—the revenues from the C3 are assumed to be the total C3 server cost multiplied by the number of C3 servers. Additionally, the revenues from the SW agent are assumed to be 5% of the total infrastructure cost served by one C3 multiplied by the penetration percentage of SW agents. In this case, the penetration percentage is 100%, since the SW agents are installed at each micro/macro DU.

III. ***Spectrum sharing revenues, infrastructure sharing revenues, RRM revenues, network slicing revenues***—include the added value multiplied by the basic SW C3 + agent revenues. Added value is the price that the product or service is sold at. The added value is assumed to increase from the initial 20% up to 50% for spectrum sharing, 30% for infrastructure sharing, 30% for RRM and network slicing. Also, the penetration percentage waves from 10% to 70% over the years for spectrum sharing and infrastructure sharing, from 20% to 40% for RRM, up to 50% for network slicing revenues. Note that, added value and penetration percentages follow the original COHERENT approach.

IV. ***Maintenance revenues***—it is usual practice to assume that maintenance is the 10% over the sum of revenues (i.e. SW C3 + agent revenues plus infrastructure sharing revenues plus spectrum sharing revenues plus RRM revenues plus network slicing revenues).

3.3 Operator

This subsection describes a techno-economic analysis of employing the COHERENT architecture and specifically the C3 entity from the Operator's point of view.

The viability of the Operator is going to be evaluated through a 7-year analysis. The Operator is going to invest on this architecture (i.e. buying the product and services from the C3 Producer) because it would like to improve the performance of its network and at the same time gain some revenues. The results of this analysis will show the economic benefits of employing the COHERENT architecture from the Operator's point of view.

The costs and revenues of the Operator are categorized into the following general groups, as shown in Table 2.

More specifically, each group is further explained below, after making the necessary realistic assumptions for business related works with similar cost-revenues methodology [12]:

I. ***Infrastructure cost***—Infrastructure includes the micro DUs and macro DUs. Specifically, DU is a hardware box with MAC and PHY layers, radios and antennas. The micro DU and macro DU cost 600 € and 4.500 €, respectively, according to data provided by OTE S.A, Greece. The macro DU/micro DU ratio is considered to be 1/10.

II. ***Cost of business***—It is actually the price that the Operator will pay to the C3 Producer in order to employ the COHERENT architecture in his existing network. A C3 producer can sell to multiple Operators.

III. ***C3 + agent related ARPU***—First of all, it is assumed that the Operator deploys the new technology for providing coverage to customers; the increase in infrastructure coverage is reflected in the yearly increase of the customer number. Each year the customer base increases 10%. Also, the indicative average revenue per user (ARPU) is 25 €, which is reduced by 3% every year, according to data provided by OTE S.A, Greece. The income generated by ARPU is partially used (starting with 20% and increasing in time to 30%) for paying the infrastructure, C3 and agents costs. The SW cost is covered by the proportional part of the ARPU.

4 Results

This section demonstrates the results of the techno-economic analysis provided in Section 3. These results give the opportunity to a future C3 Producer or Operator to examine the case of investing on the C3 entity and COHERENT architecture in general.

At first, Fig. 2 presents the costs and revenues per year for the C3 Producer. It is observed that only after Year 3 the revenues-to-cost ratio is more than 1.5. The first two years, i.e. Year 1 and Year 2, the C3 Producer needs to cover this damage, i.e. difference between cost and revenue, with alternative ways, e.g. by taking a bank loan for the required capital. It is also shown that Year 4 and Year 5 have the highest performance, since these years the C3 production and relevant sales reach their peak. In fact, according to [11], in Year 4 and Year 5, the number of C3 servers has more than tenfold increase compared with the number of C3 servers in Year 1. Also, Fig. 3, which shows the net revenues per year for the C3 Producer, proves the peak performance of the Year 4 regarding the revenues. Therefore, from the C3 Producer's point of view, it seems that it is beneficial to employ the COHERENT architecture since the techno-economic analysis results reflect the success of this investment.

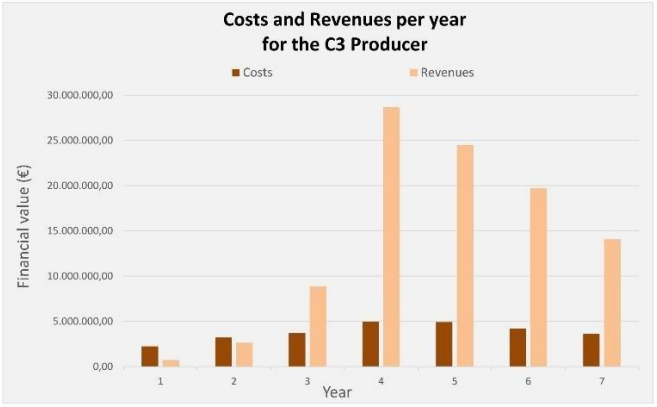


Figure 2. Costs and revenues per year for the C3 Producer.

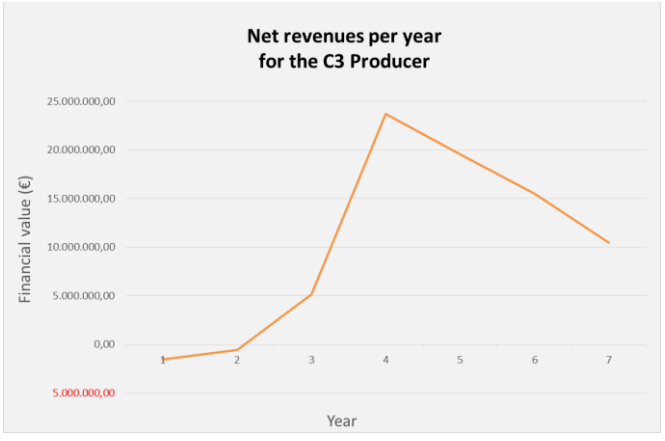


Figure 3. Net revenues per year for the C3 Producer.

Then, Fig. 4 demonstrates the costs and revenues per year for the Operator. It is observed that the revenues exceed the costs from Year 3 onwards. Only the starting years, i.e. Year 1 and Year 2, both costs and revenues follow a similar trend, but then the revenues grow extremely during the whole next period analysis. The Operator starts with limited amount of money from the customer ARPU and invests strongly in the technology; in time the investments are reduced and the customer base increases significantly, such that the Operator gets significant earnings and has limited costs. Also, Fig. 5, that shows the net revenues per year for the Operator, proves again this almost exponential rise regarding the revenues. Therefore, from the Operator's point of view, it results that is beneficial to employ the COHERENT architecture since the techno-economic analysis results reflect the success of this investment.

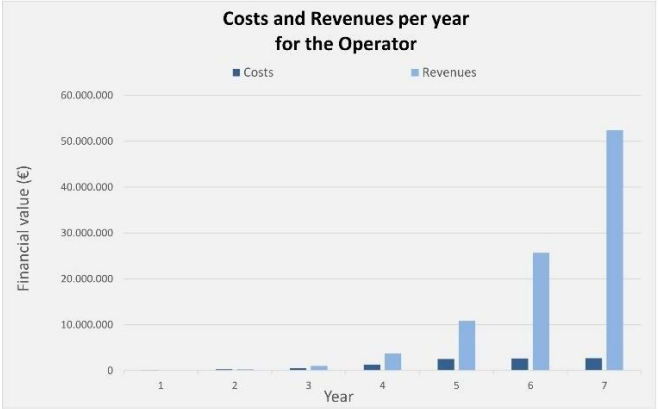


Figure 4. Costs and revenues per year for the Operator.

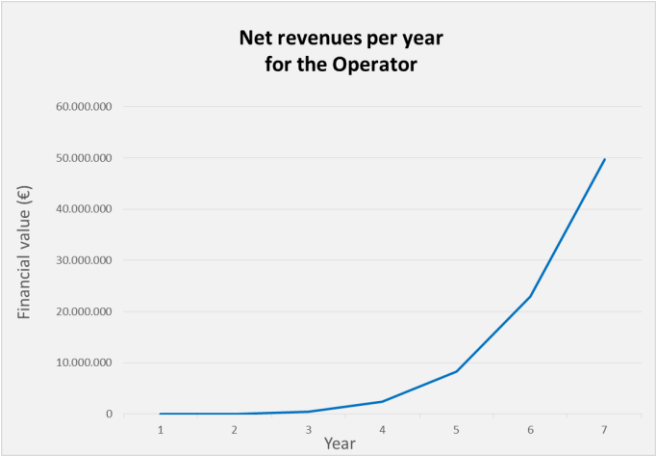


Figure 5. Net revenues per year for the Operator.

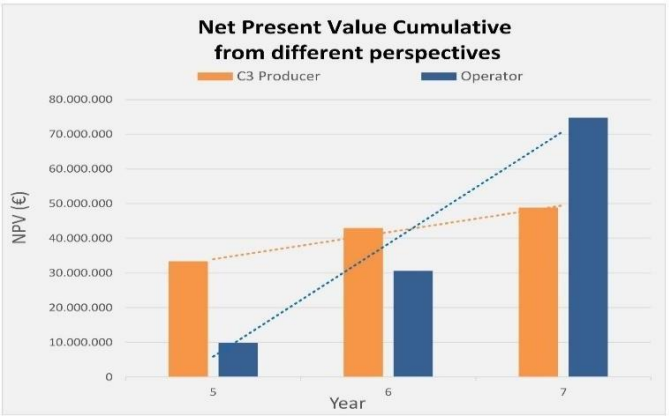


Figure 6. Net present value cumulative for both C3 Producer and Operator.

Finally, in Fig. 6, it is observed that the gradient of the NPV cumulative is higher for the Operator than for the C3 Producer. Essentially, after Year 4 the revenues for the C3 Producer slows down since the market starts to reach a saturated level of this technology and the competition is stronger. On the contrary, the Operator can impressively increase its revenues and continuously acquire new customers by providing new attractive services on the top of the COHERENT architecture.

To summarize, through this 7-year detailed financial analysis, it was proved that the adoption of COHERENT architecture could be profitable in economic terms and a viable solution for the wireless ecosystem, for both C3 Producers and Operators but with different attributes. It is also important to note that the assumptions made were modest, neither pessimistic nor optimistic. Thus, the results of the techno-economic analysis reflect the success of the COHERENT investment from both C3 Producers' and Operators' point of view and can drive to great development for future wireless networks.

5 Conclusion

This research work described the role of C3 entity and its potential technical gain value if implemented in the existing wireless communications network. Additionally, the performed techno-economic analysis showed that it could be viable for both C3 producer and network operator to implement the C3 entity in their own network.

The C3 producer is expected to make a platform that provides a lot of opportunities in increasing the financial base. In the near future, when 5G will come into the arena of network operators, there will be the need for the operators to have a platform such as C3 that controls and orchestrates the infrastructure, slicing aspects and resources.

Regarding the Operator, the C3 solution will bring benefits to him in terms of providing less CapEx and OpEx since most of the EPC-based equipment will be replaced by C3. However, the high initial cost or the time period it will take to replace all the access infrastructures may be threats to the operator.

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