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LTE-Advanced: Techno Economical Perspective

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Abstract The purpose of this research paper is to have the high level knowledge of LTE-Advanced and to study techno-economic perspective of LTE-Advanced. LTE is the predecessor of LTE-Advanced and is release 8 and release 9 of 3GPP. LTE-Advanced is release 10 of 3GPP and also Release 11 which is the more improved version of LTE-Advanced. In release 11 improvements are made and some new features are introduced to further enhance the capabilities of LTE-Advanced. The main aim of LTE-Advanced is to support the higher data rates, improved cell edge throughput and quality of service. To achieve the goals set for LTE-Advanced new technological features are introduced. These features include relay, Comp heterogeneous networks Advanced heterogeneous network feature is new and other features were taken from LTE, as LTE-Advanced is the improved version of LTE.

Keywords LTE-Advanced, Techno-economic Analysis

1. Introduction

There are different generations of mobile communication technologies, 1G is the mobile analog radio systems of 1980, s, 2G is the first digital mobile system, 3G is the first digital system handling the broadband data and LTE-Advanced is the release 10 of the 3GPP known as 4G.LTE-Advanced.LTE-Advanced provides the solution to the ever growing demands of the higher data rates. As LTE-Advanced has higher data rates, it has got higher capacity to can accommodate more number of users. LTE-Advanced has not only the higher data rate but it is also cost efficient in the long run. LTE-Advanced is cost efficient as there are fewer nodes. BTS and BSC are replaced by the eNb in the LTE-Advanced.

1.1. LTE-Advanced protocol principle

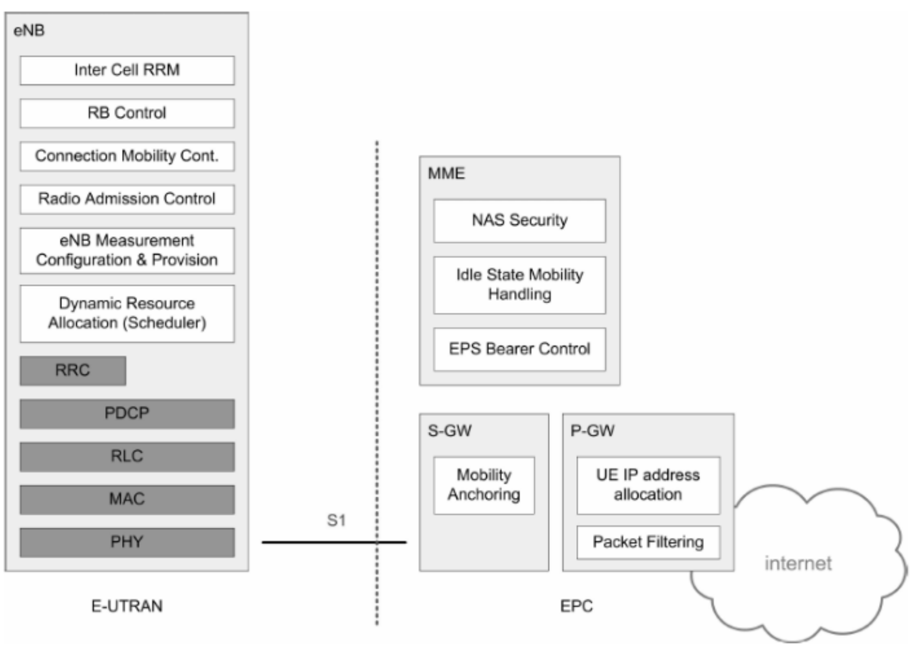

Figure 1. EPS architecture –functional description [11]

In above figure functionalities of EPS architecture entities are explained. These include eNB (enhanced node b), S-GW (serving gateway), P-GW (PDN gateway) and MME (mobility management entity).

1.1.1. LTE-Advanced user plane protocol stake

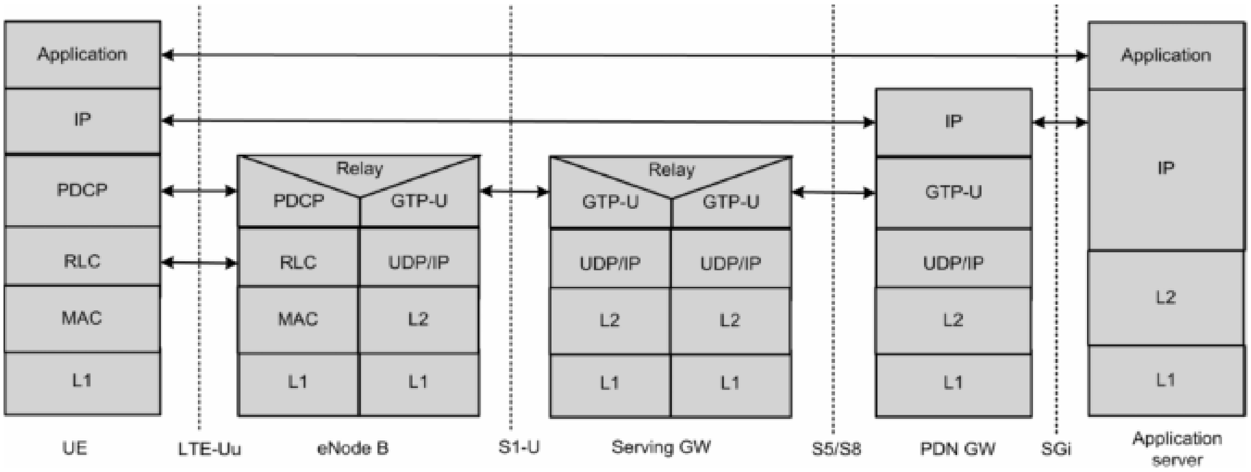

Figure 2. LTE-advanced user plane protocol stack [11]

Figure 2 shows the protocol architecture of LTE-Advanced user plane protocol stake.in User plane four layers are used namely PHY(physical), MAC (medium access control layer) ,RLC (radio link control) , PDCP (packet data control protocol).functionalities of these layers has been explained in the above figure.

1.1.2. LTE-Advanced control plane protocol stake

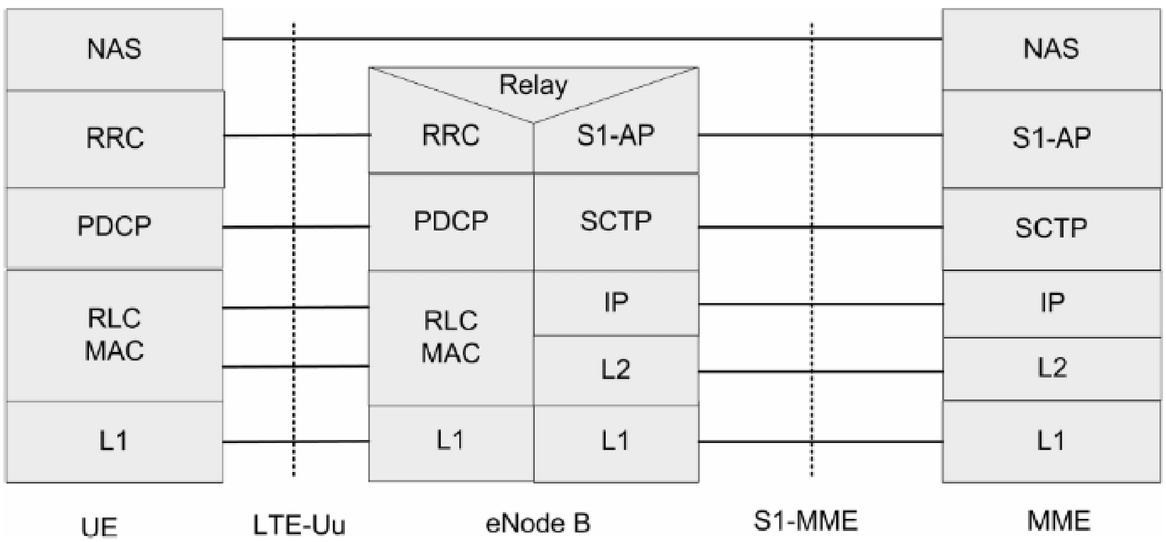

Figure 3. LTE-Advanced control plane protocol stack [11]

Figure 3 shows the control plane protocol stake for the LTE-Advanced. In addition to the layers used in user plane protocol architecture, two more layers are used. These layers are RRC (remote radio control), NAS (non-access stratum).functionalities of these layers is explained in the above figure.

1.2. Key Technologies of LTE-Advanced

1.2.1. Carrier Aggregation

Carrier aggregation In carrier aggregation several LTE component carrier are grouped (e.g. up to 20 MHz) which allows LTE-Advanced devices to use greater amount of bandwidth. Since it is important to keep backward compatibility carrier aggregation is of R8/R9 LTE carriers. LTE-Advanced supports both the contiguous and NON-contiguous spectrum. The component carrier can have a bandwidth of 1.4, 3, 5, 10, 15 or 20 MHz and a maximum of five component carriers can be aggregate.

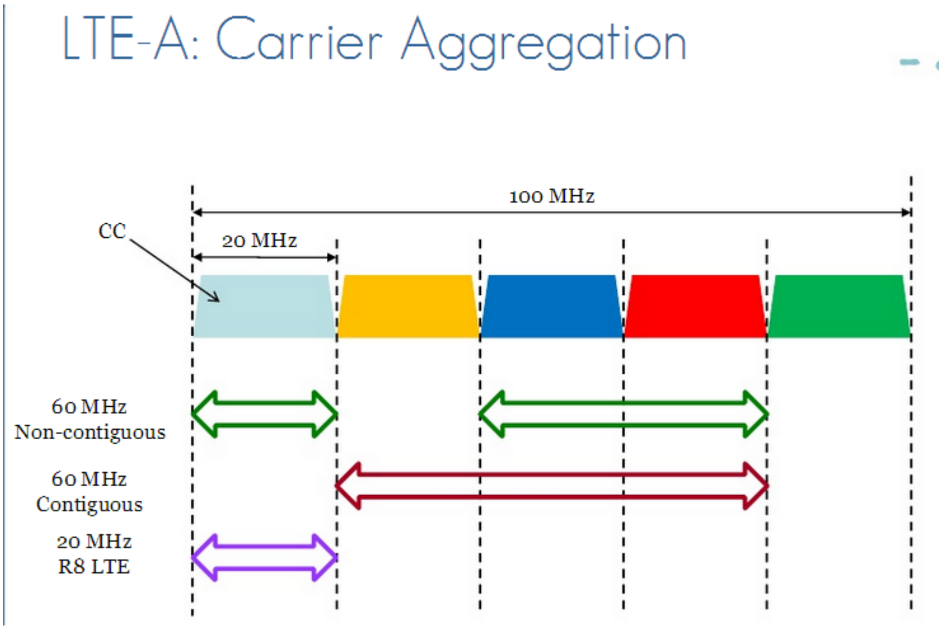

Figure 4. carrier aggregations contiguous & non-contiguous [12]

1.2.2. Enhanced MIMO

Enhanced MIMO is considered as one of the main feature in LTE-Advanced that will allow LTE-Advanced to meet IMT-Advanced requirement. Up to maximum 8X8 layer configuration with the 4x4 configuration as baseline configuration is introduced in downlink and maximum of 4X4 layer configuration with the 2x2 baseline configuration is introduced in uplink. Introduction of 8x8 maximum configuration allows to achieve high data rates while introduction 4x4 maximum configuration in uplink allows to achieve high spectral efficiency 15 bits/s/HZ with 64-QAM.MIMO technology basically makes use of multiple antennas at the transmitter and multiple antennas at the receiver. MIMO basically provides the high space diversity gain by combining the transmit diversity gain and receive diversity to reduce bit error rate and provide high capacity.

1.2.3. Heterogeneous Networks (Het Net)

Heterogeneous networks is a LTE-Advanced feature that was introduced to provide better coverage ,quality of service and high throughput at cell edge. Heterogeneous network can be defined as a network that is basically a mix of macro, pico, femto and relay base stations.

1.2.4. Relaying

Relaying is feature that was introduced in LTE and now also implemented in LTE-Advanced. Relaying technology has number of advantages. These include providing coverage in new areas, cell edge throughput, temporary network deployment, group mobility and coverage of high data rate. Relay nodes are basically deployed between the UE and eNB. The interface between the user equipment and relay node is called Uu interface, while the interface between the relay node and donor eNB is called Un interface. The communication between the eNB and RN is inband and outband. In band communication same the link uses the band that is used between the UE and eNB, while in outband different band is used. The Relay Node supports the eNB functionality meaning it terminates the radio protocols of the E-UTRA radio interface, and the S1 and X2 interfaces. In addition to the eNB functionality, the RN also supports a subset of the UE functionality, e.g. physical layer, layer-2, RRC, and NAS functionality, in order to wirelessly connect to the DeNB. There are two types relay nodes supported in LTE-Advanced namely type 1 and type 1a. Type 1 and Type 1a both has same features except that type 1 is characterized as inband RN while type 1a operates in outband.

1.2.5. Coordinated Multipoint Transmission\Reception (CoMP)

CoMP transmission and reception is ways to eradicate inter cell interference. In CoMP several antenna nodes cooperate which are geographically distributed to improve user performance that serve in the common cooperation area. In downlink, CoMP has two coordinating schemes cooperative scheduling\beam forming and joint processing. The difference between the two is that in cooperative scheduling\beam forming only one eNB transmits data to the UE, although the different eNB may share control information and in joint processing many eNB, s transmit data to the UE simultaneously.

2. LTE-Advanced Techno-Economic Analysis

In order to explain LTE-Advanced techno-economic analysis following case study is considered which has been done by Department of Informatics and Telecommunications, University of Athens, Greece [10]. LTE-Advanced techno-economic analysis has considered following areas and their results.

1. Area Modelling
2. Service and Demand assumptions/penetration
3. Tariff assumptions and data plan marketing
4. Network Dimensioning – Capacity Driven and Coverage Driven results
5. Case Study Results
6. OPEX/CAPEX tables
7. Free Cash Flows tables and Cash Balance charts

Following techno economic Model has been used in this case study.

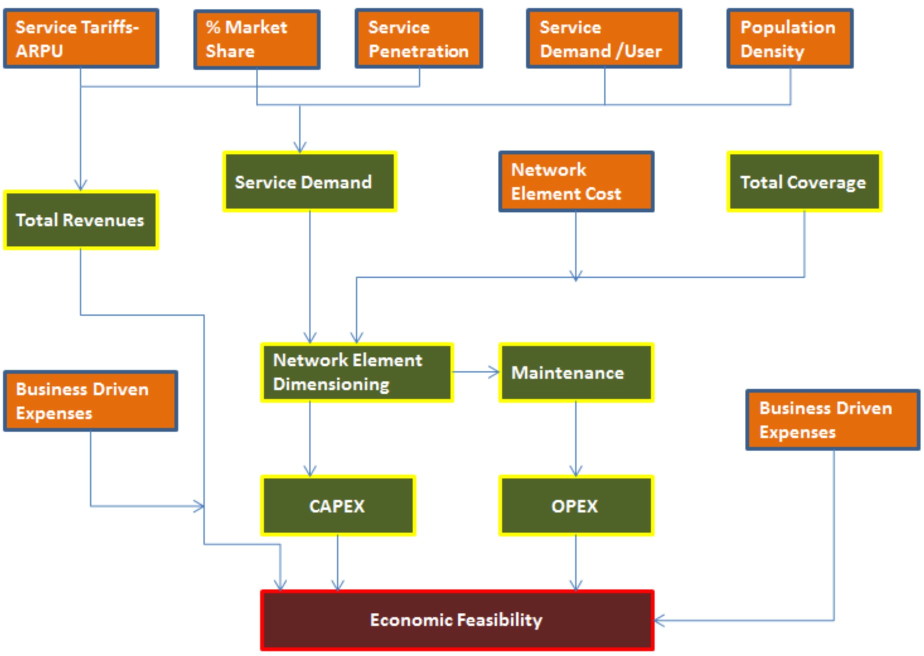

Figure 5. Techno Economic Model [10]

2.1. Area Modelling

Study Area Modelling has been used by keeping in view 3 key factors.

- Population
- Area
- Population Density

2.2. Service and Demand Assumptions/Penetration

Service and demand assumption penetration has been projected according to below graph.

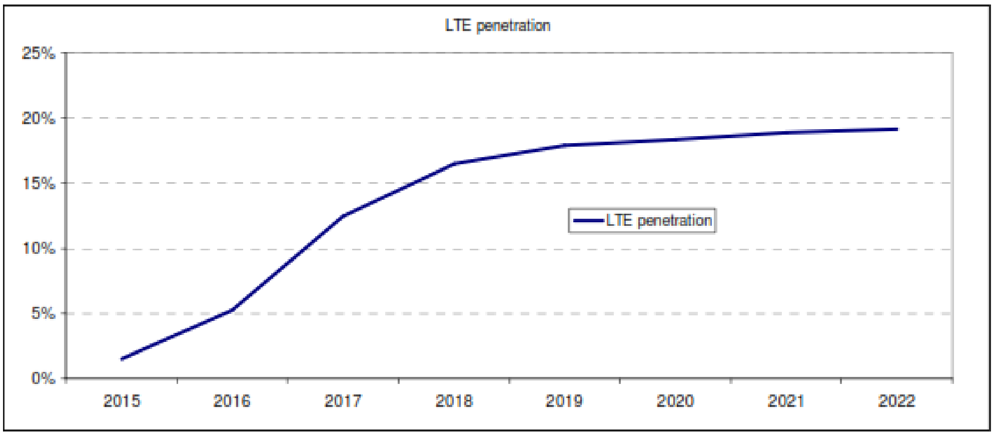

Figure 6. LTE Service and Demand Assumption Penetration [10]

2.3. Tariff Assumptions and Data Plan Marketing

Following LTE tariffs and LTE data plan marketing have been considered for the analysis.

Below data has been collected from different operators in Europe which is provided by University of Athens Greece for research analysis.

Table 1. LTE Tariffs Data [10]

Providers	Data Rates (Mbps)	Tariff (€)/month
Operator A	10-80 (data cap 30 Gb/month)	65
Operator B	10-80 (data cap 30 Gb/month)	46
Operator C	10-80 (data cap 30 Gb/month)	63
Operator D	10-80 (data cap 30 Gb/month)	70
Operator E	10-80 (data cap 30 Gb/month)	75

2.4. Network Dimensioning – Capacity Driven and Coverage Driven results

2.4.1. Coverage driven network dimensioning

Following set of methodology is used for coverage driven network dimensioning.

Define cell radius using propagation models depending on frequency used and environment (e.g. Okumura – Hata Propagation Models, Building density etc)

3 sector site: Site Area = 1,95 * 2,6 * CellRadius^2

#Sites for Coverage : Case Study Area / Site Area

2.4.2. Capacity driven network dimensioning

Following set of methodology is used for capacity driven network dimensioning

Define Average Cell Throughput based on the predicted traffic – mapping of SINR distribution.

Estimate Traffic Demand and Contention Ratio factor

OverallDataRate = #Users*PeakDataRate*ContentionRatio

#Sites for Capacity = OverallDataRate / Site Capacity

Case Study Results

Based upon all Technical assumptions/data table below results of the case study OPEX/CAPEX and Free Cash Flows tables & Cash Balance charts Tables are below as per techno economic Model considered for this case study.

Table 2. LTE techno-economic analysis Technical Assumptions [10]

Technical Assumptions								
Year	2015	2016	2017	2018	2019	2020	2021	2022
Spectrum Available	20MHz	20MHz	30MHz	30MHz	30MHz	40MHz	40MHz	40MHz
Peak Spectral Efficiency(b/s/Hz)	5	5	10	10	10	12	12	14
Users Per Cell	300	300	400	400	420	420	500	500
Peak Data Rate Mbps (nominal)	60	60	120	140	140	200	240	280
QoS Average Data Rate (80% ofcell users)	40	60	100	120	120	160	200	240
Mbps/eNB	18000	18000	48000	56000	58800	84000	120000	140000
Contention Ratio	20	20	30	30	30	30	30	30
Nominal Mbps/eNB	900	900	1600	1867	1960	2800	4000	4666,67
max users per eNB	6000	6000	12000	12000	12600	12600	15000	15000
International bandwidth cost(€/MB/year)	54,00 €	54,00 €	48,00 €	48,00 €	€ 42,00	€ 42,00	36,00 €	36,00 €
Price (ARPU)	47,50 €	45,00 €	45,00 €	€ 40,00	€ 40,00	€ 35,00	€ 35,00	30,00 €
Percentage Price Drop	0	5,56%	0,00%	12,50%	0,00%	14,29%	0,00%	16,67%
Sales (Users)	60.914	217.429	514.683	680.555	739.152	758.633	781.121	791.58
Sales Percentage Rise		71,98%	57,75%	24,37%	7,93%	2,57%	2,88%	1,32%

2.5. CAPEX/OPEX Tables

Based upon all assumptions/data used annual CAPEX & OPEX breakdown tables of the case study are below as per techno economic Model considered for this case study.

Table 3. Annual CAPEX Breakdowns [10]

CAPEX									
Components	Initial Investment	2015	2016	2017	2018	2019	2020	2021	2022
Spectrum Fees	132.384.000 €								
LTE eNB	40.365.000 €								
LTE Antenna upgrade		0 €	0 €	7.452.000 €	0 €	0 €	0 €	9.315.000 €	0 €
Access Router	3.500.000 €								
Ethernet Switch	2.400.000 €								
Relay Nodes	22.032.000 €								
Mobile ManagementEntity		5.000.000 €	5.000.000 €	0 €	5.000.000 €	0 €	0 €	0 €	0 €
PDN Gateway		1.000.000 €	2.000.000 €	0 €	0 €	0 €	0 €	0 €	0 €
Serving Gateway		1.000.000 €	2.000.000 €	0 €	1.000.000 €	0 €	0 €	0 €	0 €
Equipment Cost	68.297.000 €	7.000.000 €	9.000.000 €	7.452.000 €	6.000.000 €	0 €	0 €	9.315.000 €	0 €
Total CAPEX	200.681.000 €	7.000.000 €	9.000.000 €	7.452.000 €	6.000.000 €	0 €	0 €	9.315.000 €	0 €

Table 4. Annual OPEX Breakdowns Table [10]

OPEX									
Components	Initial Investment	2015	2016	2017	2018	2019	2020	2021	2022
Maintenance(Defected Equipment)		2.018.250 €	2.018.250 €	2.018.250 €	2.018.250 €	2.018.250 €	2.018.250 €	2.018.250 €	2.018.250 €
InternationalBandwidth Rental		4.934.277 €	17.611.992 €	37.057.392 €	49.000.176 €	46.566.702 €	47.794.005 €	42.180.642 €	42.745.428 €
Service (CoreNetwork)		70.00 €	160.00 €	160.00 €	220.00 €	220.00 €	220.00 €	220.00 €	220.00 €
Site Rent eNB (Year)	10.000 €	6.210.000 €	6.396.300 €	6.588.189 €	6.785.835 €	6.989.410 €	7.199.092 €	7.415.065 €	7.637.517 €
Site Rent RN (Year)	1.200 €	3.304.800 €	3.403.944 €	3.506.062 €	3.611.244 €	3.719.582 €	3.831.169 €	3.946.104 €	4.064.487 €
Leased Lines Rent(Transport Network)		142.776.000 €	135.637.200 €	128.855.340 €	122.412.573 €	116.291.944 €	110.477.347 €	104.953.480 €	99.705.806 €
Utilites	Watts (Average)								
BTS	900	269.87 €	296.85 €	326.54 €	359.19 €	395.110 € 434.621 €	478.08 €	525.89 €	
RN	110	146.28 €	146.28 €	146.28 €	146.28 €	146.28 €	146.28 €	146.28 €	146.28 €
Mobile ServerSwitching Center	4000	1.931 €	6.37364 €	7.01100 €	10.28280 €	11.31108 €	12.44219 €	12.81545 €	14.09700 €
Energy total OPEX		418.072 €	449.501 €	479.823 €	515.749 €	552.696 €	593.338 €	637.174 €	686.264 €
Total OPEX		159.731.399 €	165.677.187 €	178.665.057 €	184.563.827 €	176.358.584 €	172.133.201 €	161.370.714 €	157.077.751

2.6. Free Cash Flows tables & Cash Balance charts

Based upon all assumptions/data used Free Cash Flows tables & Cash Balance charts of the case study are below as per techno economic Model considered for this case study.

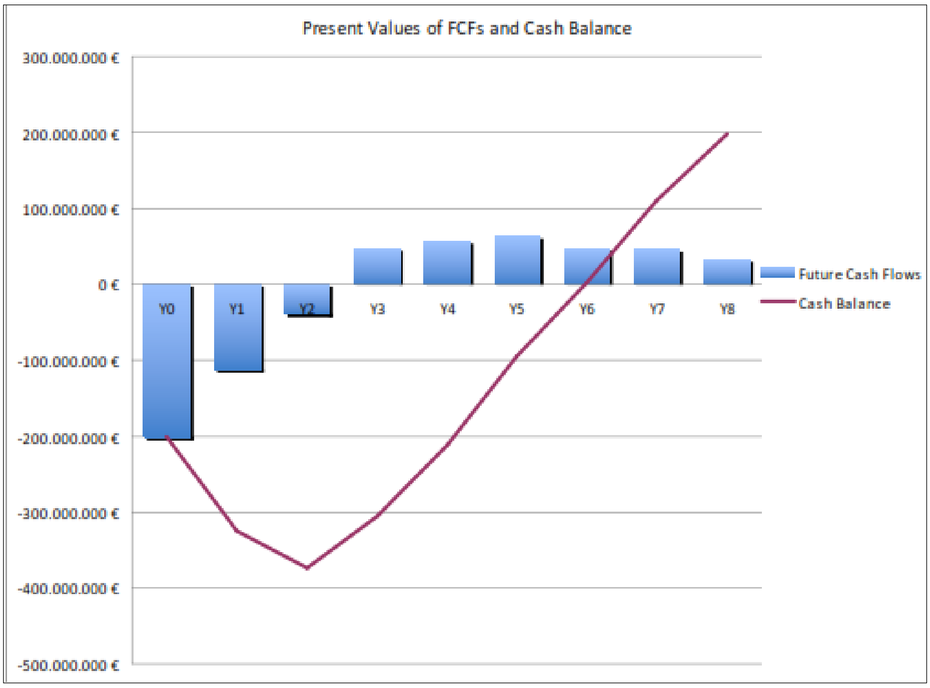

Figure 7. Free Cash Flows tables & Cash Balance charts [10]

3. Summary & Discussion

Technological features for LTE-Advanced are discussed .these features include carrier aggregation, enhanced MIMO, heterogeneous networks (Het Net), Relaying and coordinated multipoint transmission\reception (CoMP).LTE-Advanced is the Release 10 by 3GPP.

Current trends and increasing demand of data services growth also depicted above are evident that technology like LTE-Advanced is future oriented to meet the demand and supply balance. LTE-Advanced is also supporting this demand with new features as well. Strong data demand and yearly growth increase has been supported by above table projected figures.

4. Conclusions

LTE-Advanced is seen as the solution to the ever growing demands for higher data rates, high capacity and spectrum flexibility with reduced CAPEX & OPEX.

LTE Advanced key features to meet data services demand are following.

- LTE-A Peak data rates DL/UL are 10 times faster than LTE
- Spectrum efficiency: 3 times greater than LTE.
- Cell edge user throughput to be twice that of LTE.
- Average user throughput to be 3 times that of LTE.

Introduction of new enhanced LTE-A features has made it possible to meet the technological demands of high data rates in economical way with reduced CAPEX & OPEX.

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