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DESIGN OF AN INTERNET NETWORK USING HFC NETWORKS OF SAN JUAN DE LURIGANCHO

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Abstract— the design of the Internet network to provide the service using the HFC networks of the district, is an opportunity that is given to the company for growing and saving infrastructure, well it provides an opportunity for those who do not have access to the Internet for economic reasons. The current HFC network is only used for the CATV service and is not being exploited by what this design is based on the already established system that serves as a base. From these parameters, you can begin to perform the design of the network, taking into account the standards and specifications and that must take it to an optimal functioning and performance. Throughout this article, topics will be displayed it as the protocols to use, as well as operate the new network, and concepts that will be of great importance for the development of design.

Keywords— SJL, WDM, DOCSIS, CM, CMTS, DHCP, CWDM, DWDM.

I. INTRODUCTION

The district of SJL is the most populous of all Lima, and only in the year 2009 was the second district with more quantity of subscribers by operators, overtaken by the district of Santiago de Surco.

In SJL, there is a large number of small firms dedicated to different areas, either to provide a service or to sell any product, but also is a district where not all of the inhabitants has the same economic possibility, to access different services such as internet or CATV. The reason is that many of the people in this district, do not have the means and the resources to pay for services offered by other companies, it is here where the "best cable company" provide the services of CATV to these people of low resources, the advantage is the reduced price. Many these people are forced to pay for this service, and the reason is the geographical area of the district, and the location of some houses, in some cases is impossible to capture the signal of open TV. That is the reason they need to pay for CATV if they want to watch TV with great quality is necessary pay for a CATV services almost on a compulsory basis.

The HFC networks are hybrid cable coaxial and fiber optical, mainly used by CATV operators, with the purpose of providing other services without having to make large investments. These networks replaced almost in its entirety the coaxial portion leaving it alone in the part of node a user.

These networks provide a higher bandwidth and a better distribution of bandwidth that they have to provide the service. In this case is working to provide a better service, because that is only provided CATV signal, and is not making use of all network capacity, to provide a greater amount of services. That already in the district there is a certain amount of people that do not have Internet for economic reasons or because they simply had a bad experience with one of the many operators.

One of the advantages of using this network, it is the bidirectional transfer, which allows you to have greater control and be vigilant about any problem that might be. Moreover, adapt to the demand for subscribers that may arise.

In this case, the district of SJL and the company in which is based the development of this design, it comes about only giving the CATV service and want to expand their horizons, providing more services, moreover, the main consumer, are low-income people, because the price they charge is low with respect to other companies. That is an opportunity to break into the market of telecommunication, and grow to a large scale.

This design should allow the use of the HFC networks of this company to transmit various services (TV, Internet). As well as establishing the technology and the parameters, that the company must meet to provide other services, giving security information, as well as optimize the bandwidth.

The question to the current problem would be how

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to provide Internet service to the inhabitants of the district of SJL and that this, accessible to all persons who are unable to pay for the service.

Other problems that may arise are the situation of the HFC network current and that change we can make, so that may is used and that meets the requirements, and if necessary design to provide the service.

Based on these problems we can raise our objectives such as the design, verification, and description of the current network it have, as well as describe the technology that will use.

Therefore, only this network will be designed for this district, although it can take as an example for other designs.

Another point to emphasize is that this work will only base on the design and not the implementation of the same.

II. THEORETICAL FRAMEWORK

A. Network HFC

HFC networks are telecommunications systems, which, they are normally used by CATV companies thanks to its high capacity broadband since it implements the optical fiber as backbone and serves as the basis for the transmission of their signals.

The transmissions through coaxial are one-way signals, this signal only transmitted (signal down) by the same limitations to reach long distances used amplifiers in a cascade topology, and while most amplifiers used the received signal will be noisy and distorted. HFC networks allow smaller amplifiers have as reference 3 to 5, as maximum this lower employment amplifiers will decrease noise caused by cable, also, will reduce the distance that has to go through the coaxial lines. One of the advantages of combining fiber and coaxial is that allows to transmit analog signals through fiber without having to convert it to digital.

B. HFC network structure

The frequencies in descending mode they are 500-750 / 860 MHz, and even to 870 MHz and the ascendant going between 5 and 42 MHz for American standard and European goes from, 5 to 65 MHz

Typical network topologies are the type tree, ring, the main difference that has these topologies are how it distributes this signal, and under rules that governed, type tree are those where the signal travels from the header to the optical node, and it is converted to electricity to be distributed using coaxial. The second topology uses main nodes that your job is to distribute the signal and provide support to the transmitted signal, these major nodes not to convert the signal to electrical, still working with the optical fiber, and then they pass to the child nodes that are responsible for converting the optical signal to electric. These follow the SDH (Synchronous Digital Hierarchy) optical transmission standards working in ring networks. Usually ring is more expensive, but offer many improvements, such as flexibility, as well as catering facilities.

C. How is divided an HFC network

HFC networks. They are divides into several parts, and these parts dependent of the locations.

1) backbone network: this network is intended to split the signal transmitting from the head to the areas where they distribute the signal, this network are those that cover large distances and is known as "it vertebra optics" since this network is constituted by fiber optic.

2) *Distribution network:* the network serves to deliver the signal from the primary optical node to secondary, which will fulfill the function of split this signal; it can do with coaxial cable, but also fiber, depending on the distance to cover. This network can divide into several parts as a passive network, final network, secondary backbone, but it can also refer to the network of just a node in the tree-like topology.

3) Network of the last mile: is the last part of the section that goes to the Subscriber, usually use the coaxial cable of the type 0.500, RG-6 or RG-11. It is connected to the passive distribution network;

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this network can segment in two ways one of which is from the diverter until the user's home.

D. Advantages of the HFC network

Change many of their lines of coaxial by optical fiber, which lowers interference of return since the coaxial network is very noisy.
They kept the same teams either the header, as amplifiers as well as the reduced use of these same.
The network that is used is mostly a passive network since it tries to avoid the use of power supplies.

E. Modulation in HFC network

The modulation as such contains a set of techniques and tools that allow transporting information about a carrier, sinus type, one of the main advantages of the modulation is to take advantage of the communication channel, since the information must arrive in good condition, and is required to facilitate the transmission of the signal
The type of modulation is a digital modulation such as QAM and QPSK.
In addition, we can say that digital modulation is:
The modulating signal is a digital signal while the carrier signal is an analog. Also, that is a process where transform symbols that are digital, a form that suits the medium of transmission on the channel to transmit

F. Standard DOCSIS

Is a standard international, non-commercial, and this is responsible for defining the requirements of communications support and interface support for cable data systems; It covers every element that has that relationship with the infrastructure from CM (cable modem) to the terminal equipment of the CMTS operator. These specifications detail the basic function of the CM of a client such as modulation of frequency in the coaxial cable as well as encryption of data, distribution of frequencies in HFC networks.
For networks, HFC does not use the frequency range of 5 to 750 MHz, thanks to the use of fiber optics this bandwidth grows to 860 MHz, and even up to the 870 MHz
On the next Figure, it shows the entire spectrum:

- Loading data (from 5 to 42 MHz)
- Video bandwidth (from 54 to 550 MHz)
- Digital Video bandwidth (from 550 to 750 MHz)
- Download data (from 750-860 MHz)

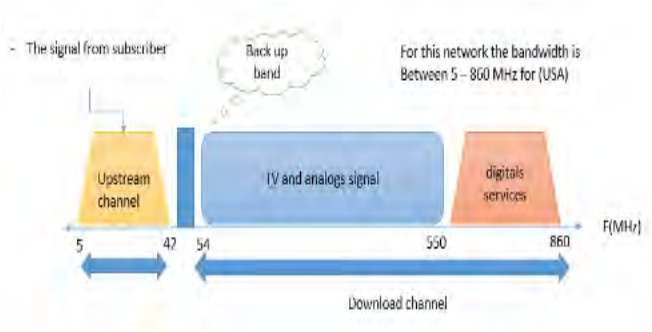

Figure 1: bandwidth of HFC network

The CMTS and CM, for registration and operation, have to make a connection between these two, so it would be to check the cable modem in the header, by DHCP registration.
This registration and allocation of IP is this assigned and recognition, is continuous from the CM to the CMTS application messages, to request permissions for Internet access.

III. PARAMETERS FOR THE DESIGN OF THE NETWORK

The HFC networks allow access to high-speed internet through CATV networks. These are connected by coaxial since the Subscriber up to the node that covers this area, and these are interconnected among themselves using the coaxial and fiber to the header.

1. *Description of the current network:* the current network of SJL district is located in a State still in a process of coaxial fiber-optic parts. Being 40% fiber and coaxial 60%,
   However, what they want is to move the optical part, which can be to the Subscriber.
   Currently only transmits CATV signals, and no other signals so only used the network one way, wasting one of the advantages of the HFC network, which is the bi-directional use, but is understood since they do not transmit data and do not need user information.

The following Figure shows the network topology that is currently in the district; this network has even clearly coaxial part.

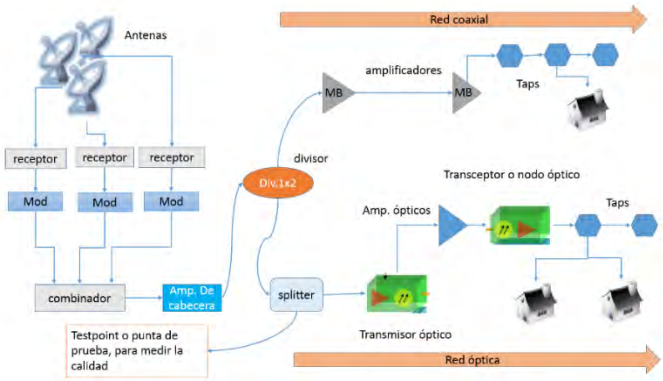

Figure 2: Topology of the HFC network that we have for the transmission's CATV

Currently is used 54 to 550 MHz bandwidth for the transmission of analog signals, and is located in State of test transmission of digital signals and are in the bandwidth of 550 to 750 MHz

San Juan de Lurigancho district spreads to other districts, like Ancon, Puente Piedra, etc., but just in SJL; it has more 25000 subscribers. While not every district has a chance to pay TV offering is not for reasons of infrastructure but, because both Movistar and Claro as they are already installed and give not only TV pay, also internet and telephony service.

The company has a capacity of service to an approximate amount of 50 000 subscribers

The service of CATV currently provided, at the level of competition the leading companies as Claro and Movistar, and have more recognition by the public, but the company has begun to extend its network since an advantage over these is the price charged by the CATV service. Since the main consumer is class C, D. aimed at families that do not have as many resources to pay, what other companies charge for their services

Companies that are more powerful in the district competition is Movistar TV, and of course to, being the latter is offering more promotions to users since it also contains an HFC network already in operation

Some of the problems that the company has

1. Currently, there is everything responsiveness by the failures of any node
2. Not using the ascending channel, nor has the equipment to another service, taking into account that the HFC network can support it.
3. In using the old network although in smaller amounts
4. Costs for the maintenance of the network

2. *Requirements for the design*: for the design must be in mind, what you have and you can use and reduce expenses. As well as making failure and what can improve for the correct operation.

a) Requirements at the level of infrastructure. It is most importantly taking as top priority to the header, since it is here where is locating the equipment for the transmission of data and CATV

b) the current space is $10m^2$ since only transmits CATV and space is very limited, since to offer one more services are needed more equipment

As the CMTS, who is in charge of managing subscriber information and provide data to each users, are each CMTS has a certain ability to manage a number of cable modems this depends on the type of CMTS chosen. On the other hand, the dimensions to expand must be equal to or greater than twice the current dimensions

c) To change the dimensions of space, air conditioning that exists, is no longer sufficient to maintain the temperature for what should be choosing to expand or change the system, maintaining a temperature of 20 ° C.

d) The use of UPS (Uninterruptible Power Supplies) is necessary because these teams remain lit to computers that are used and are of great importance,

The technical level: The technicians, who installed the equipment in the homes of subscribers, must have all the ability either to perform installations or to solve any kind of problems that may arise. Since that not only are used, equipment to measure the quality with which comes the TV signal.

The level of quality to receive CATV is 48 DB, in the highest channel and 38 dB at the lowest channel. These measurements are that can see in amplifiers

Measurements should be done both to TV as to signal that the cable modems to reach, also another point to be found is the maintenance given to the network and the infrastructure.
On the other hand, they must take into account how the cable modems are. They are installed in the homes of subscribers, and as these should be used, taking into account the convenience of subscribers be provided to existing service
Another requirement that you want to know is by subscribers, and know how they feel against firms that it provides internet service and other services. In most cases, people are not satisfied, and feel that what you pay is not quite right since the quality or signal level is not the best.
Normal consumption of internet in the district, regarding the survey can say that both consumption and reviewing video mail, and social networks are the most used, the reference sample taken is 385 respondents.
There are still 20% of population not gutter or I leave the service for the poor quality, or pro that the price they are charging them was very high on the plan that initially sought

System requirements: to provide a service in this case internet, must be a provider that gives you all the bandwidth required to distribute to all subscribers, so bandwidth calculation is paramount. On the other hand, the distribution of frequencies is 550 to 750 MHz are intended for channels of CATV transmission, whether analog or digital channels. From 750-860 MHz will be only for the transmission of data to subscribers, bandwidth down 54-860 MHz, has a relation S/R > 34 dB
For transmission in ascending ranging 5-54 MHz S /R ≥ 25 dB, this sense has lowest ratio signal noise due to the frequency range is dirtier, seeing it from an electromagnetic point of view. The presence of various commercial broadcasting of short wave, citizens band signals. The bands of commercial broadcasting these very harmful for CATV HFC networks, because they have many power stations.
For the calculation of the required bandwidth to be used the following:

$$BW = GXC$$

BW: bandwidth to pay

G: bandwidth that you want to use. It is which it guarantees the user will have; Peru guarantees the user about 15%

C: number of people using the internet at the same time this value varies greatly, but must be approximate to the calculation, and this is as real as possible.

It will be used to subscribers currently has

TABLE I
This table is denoted the number of subscribers that the company currently has. Also, regarding calculation for bandwidth.

Total of subscriber	N° using internet	N° using internet and download
25000	40% => 10000	30% => with respect to subscribers : 3000

3000 x (two Mbps with 15 % guaranteed): 300 Kbps

3000 x 300 Kbps

3000 x 0.3 Mbps = 900 Mbps ≈ 1000 Mbps

For the calculation of the capacity of each channel where data signal will be sent, we will rely on the Shannon theorem, since it indicates the capacity of the channel, knowing that this will be the theoretical rate of clean data.

$$capacity = BW \log_2(1 + \frac{S}{N})$$

Returning to the problem, the data that we have are
Capacity of = 1000 Mbps
American standard uses 6 MHz channels
BW = 110 MHz, always working in the worst case (with DOCSIS 3.0 you can reach more than 110 MHz, with around 16 CH working in simultaneous), proceed to calculate the amount of channels that we have both to 110 MHz

$$\frac{110 \text{ MHz}}{6} = 18.33\ CH$$

We have 1000 Mbps we calculate how much would have to endure each channel

$$\frac{1000\ Mbps}{18.33\ CH} = 54.55\ Mbps/CH$$

Replacing in the equation of Shannon.

$$10\log(\ 2^{\frac{54.55\ Mbps}{6\ MHz}} - 1) = \frac{S}{N_{dB}}$$

$$10\log(\ 2^{\frac{54.55}{6}} - 1) = \frac{S}{N_{dB}}$$

$$27.36067\ dB = \frac{S}{N_{dB}}$$

Then you can use 64 QAM

Permitted levels of signal-noise ratio will depend on the modulation chosen, for the QPSK upwards, the S/R >21dB

If you use 16 QAM modulation, in upstream the S/R > 24dB. And for downstream, 64 QAM and 256 QAM are 25 and 33 dB respectively

To take as a reference level of modulation, we use the model of Nyquist. We will calculate the level needed for the rise of the signal, and then we will use to calculate the theoretical capacity to Shannon

$$C = BW \log_2\left(1 + \frac{S}{N}\right)$$

According to the standards rise signal SNR relationship should be greater than the 24dB, in modulation 16 QAM that passing to number serious 251.18, recalling that we have a bandwidth of 6 MHz, then the equation would be as follows.

$$C = 6x10^6 \log_2(1 + 251.18)$$

$$C = 47.86\ Mbps$$

Now taking about the theorem of Nyquist on Shannon, we can calculate the levels needed to reach this speed. However, this value is reference noise not considered

$$C = 2\ W \log_2 M$$

$$2^{\frac{C}{2W}} = M$$

$$2^{\frac{47.86}{2(6)}} = M$$

$$15.87 = M$$

$$15.87 \cong 16\ QAM$$

3. *Description of the technology used*: To use standard is DOCSIS 3.0, because the DOCSIS 3.0 standard is a more up-to-date and more stable standard, which incorporates many advantages and improvements over its previous versions since it increases the bandwidth in cable modem services, as well as also allows greater scalability and provide a greater number of services

   The main functionality or advantage of because it uses on its predecessors is the channel bonding that allows increasing the bandwidth as much for those subscribers, which have individual service This is due to the multiple carriers that can work at the same time or simultaneously thus in this way could be high speeds data transmission, which would be beneficial to be able to provide higher transmission speeds and to behave network efficiently.

4. *Design of the network*

   It is designed for this service network, the network to be used in the area of rush will be of type tree, that is to say in the location of the branches be used cable coaxial of 0.500 inch diameter, and for take-offs where you do not wish to go further or secondary branches saw otherwise. You can use the RG-11, and for the connections to the homes of subscribers use RG-6 cable.

This network will be 90 TV channels on the market and will have to pass the data to households, for this header, where all signals are operating to transmit a carrier, and this has a bandwidth of 6 MHz

For the backbone network as well as the distribution used fiber optics of type single to cover long

distances being usable wavelengths of 1310, 1550 nm
The current network is using 1310 nm wavelength
However, a solution since the beginning was not designed the network to receive signals from Subscriber, is use a WDM one of the possible solutions, even if we have to choose what type of multiplexer choose taking into account benefits and investment to make. DWDM and CWDM, the first being the most expensive but providing a great advantages, is one of the main causes of using a multiplexer to send and transmit through the same fiber, but at different wavelengths, improvement and solves much of the restraints of a company of CATV HFC network, the following image shows more clearly.

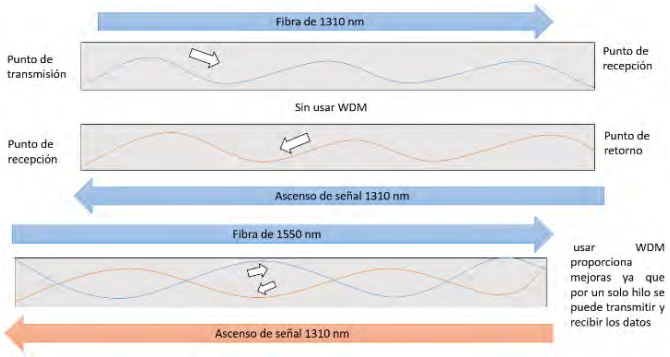

Figure 3: How is working WDM

The types of cables used are Multifibre, this fiber is bidirectional, and these are used, when the distances to travel, are quite significant. The main types are tight buffered or loose tube also, and coatings adjusted, these fibers are made of glass, with 125-micrometer glass coating, and a plastic sleeve from 250 micrometers, this fiber is 96 threads. Sections of 5 Km, 4 Km, and 2 Km will use
Around 40 optical will be utilized nodes using a tree topology, using over 35 nodes already positioned in the district.
The factors of passive elements than you consider as assets, which are the amplifiers, 60VAC to 15 sources, as well as the taps, couplers, power inserter, etc.

5. *Design in the houses of the Subscriber*

The selected cable is typical of 0.500 inch for the network, and for the House of the Subscriber a RG-6, and if you want to make a small extension to enlarge the network to a small area and not require to use 0.500,
could be used the RG-11, since when used, the RG-6 at greater distance would have many losses , and RG-11 cable has fewer losses than RG-6 at greater distances, for this same reason the 0.500 was chosen due to its good performance at high frequencies, and also for their losses which are very low
This cable pass signals from video and audio, i.e. more than 90 channels, these cables have a 75 OHM impedance.
The distance that must be the pole to the House network must not exceed 100 m; always seek the nearest Tap installation. The level of acceptable quality, in the case of TV, must be between 60 dBu and 70 dBu.
The following image shows how the rough would be.

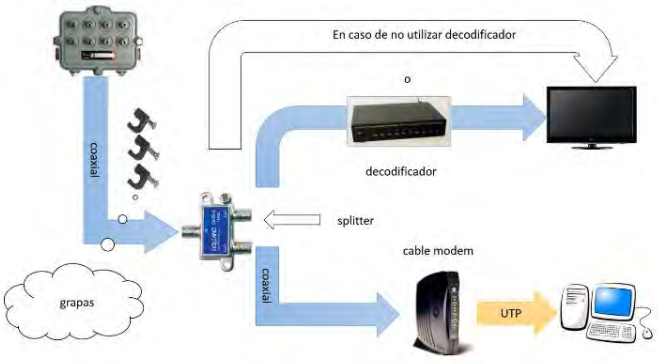

Figure 4: installations in house subscriber

6. *Design of header*

The first point is the use of a larger space, then space must pass 10 square meters to 20 this measure, it is possible because there is a new location for the header where the available space is double
Another point is the use of an air conditioner more and that this will serve as a backup to faults of which is in operation.
The use of 11 UPSs to prevent any failure of electric power, which could occur and since the generator, would soon turn, these UPSs give us this time, rather than the generator to become operational
Use won space to install the CMTS, which is use to connect to all subscriber modems cables, use 7 line cards, for a start then the capacity of this network

You can increase each CMTS, is capable of handling a capacity of 4000 CM, taking into account the recommendations proposed by CISCO, which tells us.
By able to a CMTS this is line card support a capacity of 1000 to 1200 modems, in other words, must be 200 modem for receiver, so the use of these 7 cards,
Which include within this CMTS would give us to manage a number of more 28 000 CM, the thought CMTS are the *Arris cadant C4,* which comes with support for DOCSIS 3.0.
The temperature which must be must be 19° C - 21° C, in other words, to save space, current air-conditioning and couldn't cover the entire area for which you will have to add another

7. Viability of costs and benefits

For the calculations, first, it is necessary to raise the needs that, we have at present, and know all the teams it is will need for the project. Also, what the cost of these teams is.
The cost for head elements is 44890 dollars; this value is for all the costs of teams necessary for the head.
Now it is necessary to proceed to realize a selection of passive teams that will be necessary for the network, between these the TAPs, etc.
The cost of the passive teams is 3176.75 dollars, now the cost necessary for the external plant so much of optical fiber as well as of coaxial this about 339804.75 dollar.
The sum of all these costs will give us the fixed investment necessary for the project:

Expenses foresaw for the design

E. Headend	$ 44980.97
E. external plant	$ 339804.75
Total	$ 384785.72

The Total in the national currency
S/ 1, 269,792.88

On the other hand, now it is necessary to consider the expenses to maintain the network. It is here where there enter the wages of the workpeople, expenses the providers of service, general expenses like water, light, etc.

The expenses to maintain the network

- Posts quantify $ 4000
- Pay to provider $ 30000
- Expenses for maintenance of the network $ 3700

On the other hand, it is necessary now to obtain the values of the TIR, VAN; this will help us to have a vision of the project of the viability of the project likewise to be able to know how long will be difficult to recover the money invested with PBP (payback period).
Now the values of this project, which demonstrate the practicality, it is be described next.
We take a VAN bigger than zero as what shows us, that the project is viable in the conditions at which one has employed the table of flow.
Of the same way the TIR, it shows us, that we have a project practicality of 84 % to be successful, this value they are referential and in practice, they can change.

$Vt_1 =$ cash flow
$I_o =$ initial investment
K= inflation rate

$$VAN = \frac{Vt_1}{(1+k)} + \frac{Vt_2}{(1+k)^2} + \frac{Vt_3}{(1+k)^3}\frac{Vt_4}{(1+k)^4} + \frac{Vt_5}{(1+k)^5} - I_o$$

$$VAN = \frac{87661.0}{(1+0.15)} + \frac{740702.63}{(1+0.15)^2} + \frac{1.126328.99}{(1+0.15)^3} + \frac{1806229.99}{(1+0.15)^4} + \frac{2195338.99}{(1+0.15)^5} - 541719.42$$

$$VAN = 2380454.08$$

TIR = 84 %

VAN < 0 pushed back project
VAN > 0 approved project
VAN = 0 it does not generate losses or profit

The value of the TIR indicates you that so viable a project is, and it is very useful to determine the future of a project, as well as its implementation.
If is necessary calculate the time to recover the money of the investment. It simply takes the following.

$$PBP = [\#year\ of\ negative\ VAN] + \frac{|Last\ negative\ VAN\ |}{cash\ flow\ value\ of\ the\ next\ period}$$

$$PBP = [1] + \frac{|-76226.95|}{740702.63}$$

$$PBP = 0.897\ year$$

Now if we consider the year zero, the before answer would be.

$$PBP = [1 + 1] + \frac{|-76226.95|}{740702.63}$$

$$PBP = 1.897\ year$$

IV. ANALYSIS OF RESULTS

- The current HFC network you must be many changes but, the redesign of the network is something that was necessary since the only thing that is conveyer is TV and not data.
  Activities, so that all the planned objectives were studies.
- The description of the network allowed knowing the situation of it against other companies, helped to know the capacity of the network and that it can withstand.
- The current network has many needs, at the level of infrastructure, such as space, which uses the header since it fit to data transmission equipment are incorporated here in this area also
  - The current air conditioning round 21° C and 20° C is required for this network so the change will take place
  - The equipment used must comply with the requirements of the DOCSIS 3.0 standard
  - This network enables high flexibility and savings for the operating companies, so it becomes a great opportunity for small businesses that wish to provide more services
    The standard 3.0 offers greater stability with respect to its predecessors and higher transmission speed and both upstream and downstream equity
  - The model for design is used in a hierarchical fashion naming parts of the network and develop the design on each area taking priorities that benefit to the network

V. CONCLUSIONS

1. Current HFC network can provide another service, but should still be adjustments and redesign some points so that it complies with DOCSIS standards.
2. The HFC networks are a means where the signal is affected by electrical signals. This could cause problems, in the same way, the inappropriate use of amplifiers could generate noise, so these aspects, you need to take a minute to for reed and see if all is all right
3. The use of WDM (multiplex) is important and an opportunity to avoid large capital costs since it allows better control of bandwidth and improves the performance of those networks which in principle were not designed to transmit more services
4. To check the network, it is necessary to propose solutions to possible technical problems of the company to provide another service this they must comply or solve existing problems, since these can harm the network in the future. In this same way in the polls was reflected as the quality of service by technicians is not the best. Therefore, the training must be teaching so that the installer can have character and have knowledge of the entire network and to provide solutions to problems that occur at the time.
5. One of the great advantages of this design is that it has sufficient capital for investment and the subscriber acceptance district.
6. Calculation of viability is very important value, and is also referential and highly successful shows you can have the project; these calculations were performed using approximate values and it was found that the project has a feasibility of more than 84% proving that you can implement.

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