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Abstract:

This deliverable describes a business plan referred to the deployment of the PLC technology considering the initial project R&D results.

This document is an update to the original business plan (D1.2B v0.2), delivered on June 2003. Information from commercial PLC deployments started on 2003 has been added.

Keywords:

Business Plan, IPv6, PLC, QoS.

Revision History

The following table describes the main changes done in the document since its creation.

Revision	Date	Description	Author (Organization)
v0.1	20/06/2003	Document creation	Chano Gómez (DS2)
v0.2	30/06/2003	Final edition and review	Jordi Palet (Consulintel)
v1.1	20/06/2004	Document creation (based on D1.2B)	Chano Gómez (DS2)
v1.2	05/11/2004	Finish details before submission to mailing list	Chano Gómez (DS2)
v1.3	07/11/2004	Final PSC review	Jordi Palet (Consulintel)

Executive Summary

Within this document, a PLC deployment business plan is provided, considering the initial R&D results of the project and the experience gained in several commercial PLC deployments started during year 2003.

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1. INTRODUCTION

This document intends to be a description of a simplified business plan for analyzing the main technical and financial aspects of deploying a Power Line access network that provides IPv4/IPv6 services.

The actual analysis is performed in a companion Excel file, whose main parameters are described here.

The model does not intend to be very detailed. It only tries to give a "first sight" approximation for the main figures involved in the analysis. It is useful for discovering which factors have a stronger effect in the model.

For example, it can be used for getting answers to questions like:

- Is the business case more sensitive to the price of repeater equipment or CPEs?
- How should I redesign my network if I decide to upgrade my service offering from 512Kbps to 1Mbps?
- What is the effect of doing a transition of customers from IPv4 to IPv6?
- What effect may have EMC regulation on my network deployment costs?

The model does not try to follow standard accounting practices, so it does not go into the fine details of classifying things as investments or expenses, or calculating asset depreciation or profit taxes.

This is the second major version of the business model developed by the 6POWER project. During the last year, at least two commercial PLC deployments have started in Spain, with 6POWER partners involved in both of them. The experience gained in those deployments has influenced this second version of the business model.

This version has several differences with the previous one:

- Some factors have been simplified (for example, the structure of the optical backbone, or the differentiation between residential and business customers).
- Other factors have been added (effect of maximum PSD allowed by regulation, or percentage of customers with an IPv6-enabled PC)
- Added more explanation for readers that may want to customize the business model for their own purposes.

2. NETWORK MODEL

The business plan makes some assumptions about the underlying network topology. These assumptions are needed for simplifying the problem, but they still keep the model general enough to be useful for a large variety of topologies.

The network model is shown in Figure 2-1.

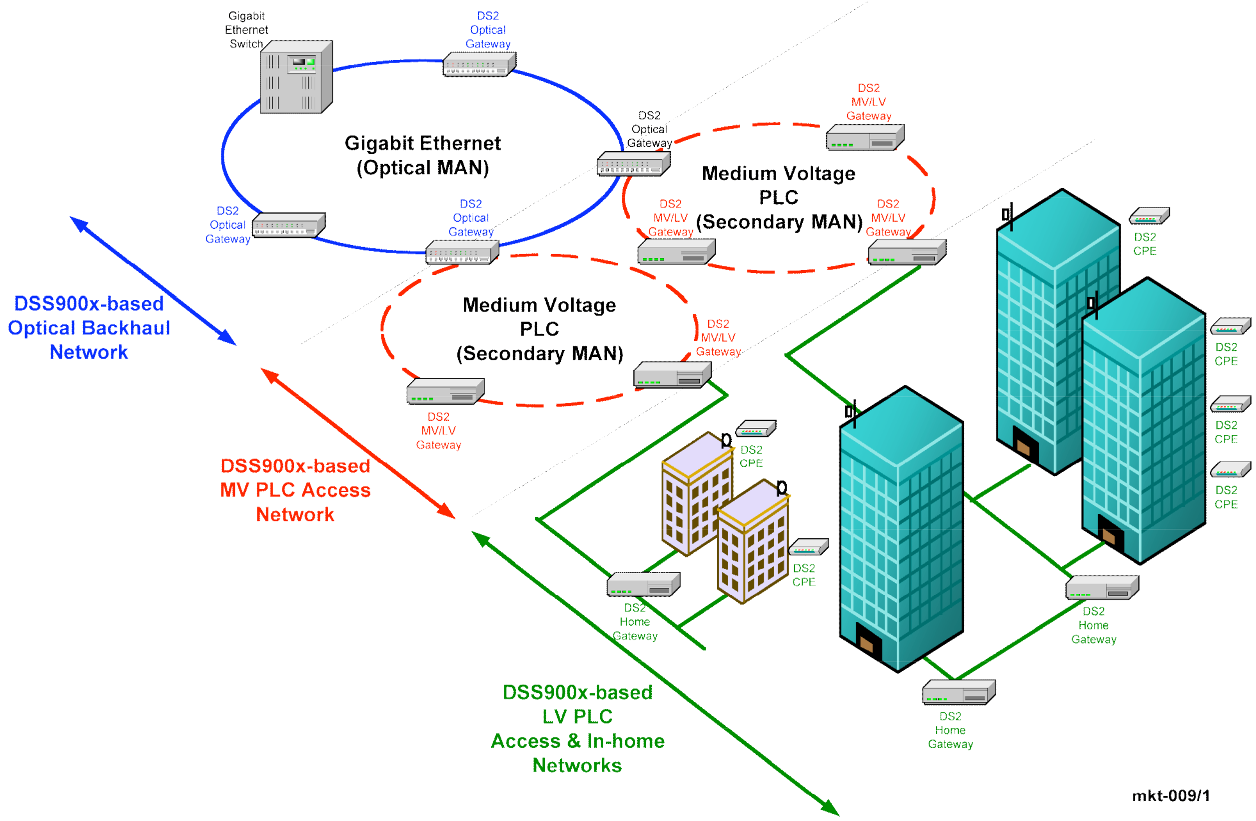


Figure 2-1: Network Model

The whole network model is based on a hierarchy of networks:

- The Low-Voltage Power Line network (LV-PLC) includes all equipment (CPEs and repeaters) that connects to a given transformer. This network is connected to the Medium Voltage Network (MV PLC) by means of the Transformer Equipment (this includes the LV Head-End and the rest of equipment required for providing MV connectivity). The LV-PLC network has a tree-like topology, with repeaters "hanging" from the TE, and CPEs hanging from the repeaters. In some cases (long distances or reduced PSD forced by regulation), intermediate repeaters may be needed (one repeater hanging from another repeater).
- The Medium-Voltage Power Line network (MV-PLC) uses the existing Medium Voltage as a backhaul for the LV cells. The MV Power Line equipment is similar in concept to LV PLC equipment, although it includes special features required for handling one or several multi-megabit traffic-flows, and makes use of special coupling devices for injecting the signal in the MV grid. It can have ring, tree or linear topology, so in the business plan it is described as a "MV PLC cluster". Each PLC cluster is connected to the next hierarchy level through an Optical POP.

- The Optical Metropolitan Area Network (OMAN) provides connectivity to MV PLC clusters. It is typically based on Gigabit Ethernet over Optical Fiber, although the specific topology to be used is strongly dependent on the characteristics of the existing Telecommunications network. For example, Ethernet over SDH technology is being used in several commercial PLC deployments. Details about this part of the network will not be covered in the business model, as they are not PLC-specific.

Connection between each level is done by Points of Presence (PoPs):

- LV networks are connected to MV networks through the Transformer Equipment (TE).
- MV PLC Clusters connect to the OMAN through Optical PoPs.

These PoPs can be layer-2 bridges or IPv4/IPv6 routers.

The main ideas behind the model architecture have been extracted from several Power Line trials and deployments worldwide in which 6POWER partners have been involved (Spain, Italy, Portugal, USA, China, etc.), so it is a proven model.

3. MODEL PARAMETERS

The model features several parameters that can be tuned in order to simulate several possible scenarios. These parameters include both technical (distances, bandwidth, equipment performance, etc.) and economic parameters (equipment costs, installation costs, service pricing, demographic distribution, etc.).

The model simulates the evolution of the business for 5 years. This means that each parameter can have a different value each year, which can be useful for reflecting factors that evolve with time: Cost reductions, productivity increases, etc.

3.1 Network Topology

3.1.1 Low Voltage Network

The main input parameters here are:

- Average number of buildings per transformer. This is typically between 5 and 15 in European urban areas and lower in North American residential areas.
- Average number of repeaters per building. This factor is technology dependent (different technologies have different coverage performance and might need more or less repeaters). Additionally, this factor is also dependent on the transmission power level allowed by regulation in a given area, as described in Section 3.9.
- Average number of homes per building. This can be calculated as (average number of floors) x (average number of homes per floor).
- Penetration Rate. This is the percentage of covered customers that actually sign for the service. By “covered”, we mean that the customer lives in a building that has PLC service. In this version of the business model, we have calculated service penetration as a function of how “competitive” the PLC service is, in terms of price, performance and allowed applications, as modeled in Sections 3.10 and 3.11.
- Total customers. This is the total number of customers in the network, computed as a function of previous parameters.

3.1.2 Medium Voltage Network

The main parameters here are:

- Average number of transformers in a MV PLC cluster. Existing networks have an average number of 7-10. This value is expected to increase every year as technology improves and longer distances can be covered. It is mainly dependent on average distance between transformers, number of customers per transformer and available bandwidth.

3.2 Equipment Technical Features

Main parameters:

- Average speed for the LV link between transformers and CPEs.
- Average speed for the MV link between transformers.

3.3 Equipment Costs

Main parameters:

- CPE cost. In the default model, this is supposed to be a Layer-2 PLC-to-Ethernet/USB bridge, with an integrated VoIP (H.323 and/or SIP) gateway.
- Repeater cost. A layer-2 PLC-to-PLC bridge.
- TE cost. Includes LV HE and MV connections. It can be a router or a bridge.
- Optical POP. A switch or router with Gigabit Ethernet (for the SMAN side) and Fast Ethernet (for the PLC side). Some PLC vendors provide PLC equipment with integrated Gigabit Ethernet interfaces.

3.4 Installation Costs

Main parameters:

- CPE installation cost. In case a technician needs to be sent for installing a CPE (see below for a parameter that says how often this should happen), this includes the cost of going into the house, working and traveling time, etc. It can become zero with a full-fledged autoconfiguration set of features.
- Repeater installation cost. Materials and staff needed for performing the installation and configuration of this device.
- TE installation cost. Materials and staff needed for performing the installation and configuration of this device.
- Optical POP installation. Materials and staff needed for performing the installation and configuration of the Optical POP.

3.5 Operations Costs

In this section the following aspects have been considered:

- Percentage of CPE installations that require a technician. This parameter is critical for the success of the deployment. It is normal to be high (around 20%) at the beginning of the network deployment, and then going down rapidly as the installers learn the best practices for repeater installation (problems with CPEs are typically caused by badly installed repeaters).
- Operations and Maintenance costs. This is the cost of reconfiguring equipment, upgrading software versions, replacing failed equipment, routine network optimization, etc.
- Customer Support costs. This is the cost of providing telephone customer support to end-users. This is only used in case the utility provides the final service to the user. If it chooses a “carriers’ carrier” model, customer support activities would be carried out by a different company.
- Service Provisioning costs. This is the cost related to all technical activities that are performed in order to activate service to a new customer that has just signed in to the service. In an IPv4 network, this would include assigning an IP address or provisioning a PPPoE account. For IPv6 customers, this cost is modeled as negligible, because IPv6 autoconfiguration features remove the need for any IP provisioning.

3.6 Commercial Parameters

The main commercial parameters we have used in this simplified model are:

- Installation fee charged to new customer.
- Monthly fee charged to customers.
- Churn rate. It is the percentage of existing users that discontinue their subscription every year. In our model, this is dependent on the perceived quality of the service provided to customers. If SLA (Service Level Agreements) requirements are not met, customers may cancel their subscriptions.

3.7 Service Parameters

The main service parameters are:

- Bandwidth included in the SLA (service level agreement). Default value 512 Kbps.
- QoS for customers (percentage of time the SLA is satisfied). Default value is 90%.
- Concurrency factor during peak hour for residential users. Default value is 10%.

3.8 Other Costs

Here we include:

- Marketing costs. Average cost per new customer (advertising, paper documentation, etc.).

3.9 Effect of EMC Regulation on Equipment Requirements

Currently, European regulation affecting PLC technology is under a revision process. Specifically, the maximum allowed electric field emission is under discussion in several regulatory bodies, and this will have a direct impact on the maximum allowed injected power level (PSD, “Power Spectral Density”, measured in dBm/Hz).

In this document, PSD limitations are taken into account with a simplified model:

- A flat channel with an average attenuation of 0.4 dB/m for the frequency band below 10 MHz. This overly simplified model included propagation attenuation, taps attenuation, etc.
- A flat noise floor with a PSD of -120 dBm/Hz.
- A minimum SNR of 15dB is required for correct equipment operation.

With this model, maximum distance covered by a repeater can be estimated as:

$$D_{\max} = \frac{PSD_{TX} - PSD_{NOISE} - SNR_{MIN}}{ATT_{dB/m}} = \frac{-50 - (-120) - 15}{0.4} = 137.5\,m$$

So, how is this translated into a number that can be used for estimating the required number of repeaters? We need to know if 137.5 m is enough to connect a building or if additional repeaters will be needed.

In order to do that, we model the transformer-to-building distance with a Gaussian distribution, with an average distance of 100m and a standard deviation of 50m. Using this numbers we can estimate the probability of requiring one repeater, two repeaters, three repeaters, etc and then compute the expected number of repeaters per building.

The following Figure shows a sample Gaussian distribution, with mean 100m and standard deviation of 50m. Obviously, the peak of the distribution is found in 100m, with the majority of the distribution in the range from 25m to 175m.

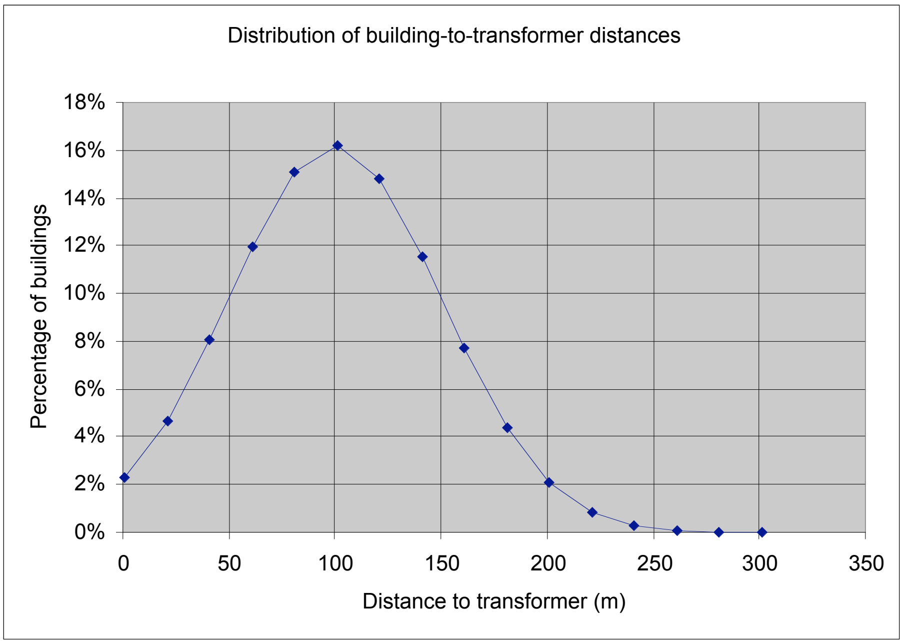


Figure 3-1: Statistical Distribution of Building-to-Transformer Distance

The following graph shows the "cumulative probability function" of the same variable (distance between building and transformer). This graph is very useful for estimating visually which percentage of buildings is below a certain distance.

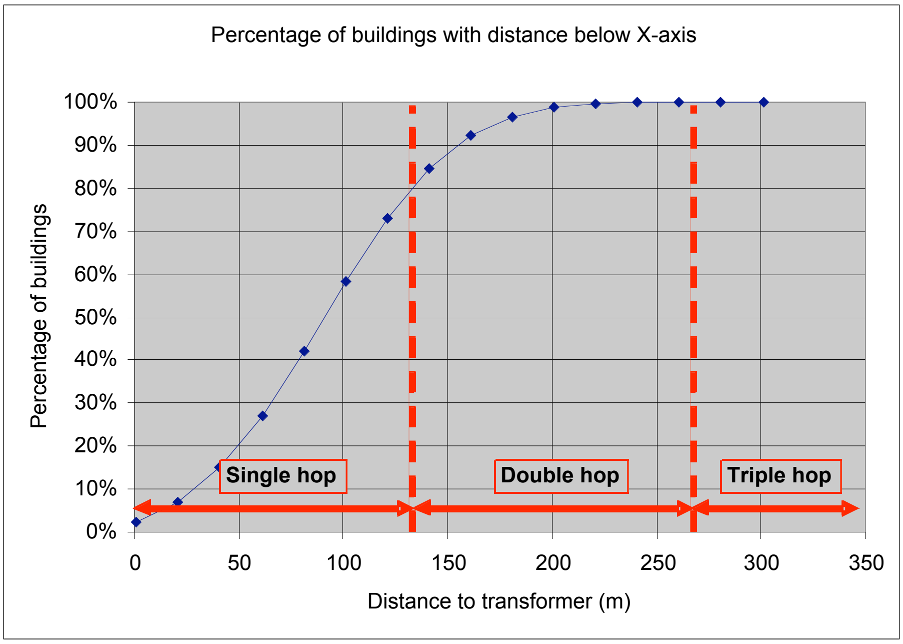


Figure 3-2: Cumulative Statistical Distribution of Building-to-Transformer Distance

For example, we can easily see that approximately 80% of buildings are below the 137.5m threshold, thus getting direct connectivity with the transformer without requiring any extra repeater. 100% of the buildings are below the 275m threshold, which means that practically all buildings can be connected to the transformer with only one auxiliary repeater.

We can aggregate all these numbers and compute a single figure that represents the average number of repeaters per building, using the following table:

		PSD (dBm/Hz)	**-35**	**-40**	**-45**	**-50**	**-55**	**-60**	**-65**
distance (m)		Max Length (m)	175	162.5	150	**137.5**	125	112.5	100
1	0.00112366	2%	1	1	1	**1**	1	1	1
21	0.0022901	5%	1	1	1	**1**	1	1	1
41	0.00397726	8%	1	1	1	**1**	1	1	1
61	0.0058861	12%	1	1	1	**1**	1	1	1
81	0.00742308	15%	1	1	1	**1**	1	1	1
101	0.00797725	16%	1	1	1	**1**	1	1	2
121	0.00730525	15%	1	1	1	**1**	1	2	2
141	0.00570073	12%	1	1	1	**2**	2	2	2
161	0.00379086	8%	1	1	2	**2**	2	2	2
181	0.00214812	4%	2	2	2	**2**	2	2	2
201	0.00103727	2%	2	2	2	**2**	2	2	3
221	0.00042681	1%	2	2	2	**2**	2	2	3
241	0.00014966	0%	2	2	2	**2**	2	3	3
261	4.4717E-05	0%	2	2	2	**2**	3	3	3
281	1.1386E-05	0%	2	2	2	**3**	3	3	3
301	2.4703E-06	0%	2	2	3	**3**	3	3	4
			1.078	1.078	1.154	**1.27**	1.271	1.422	1.614

Figure 3-3: Average Number of Repeaters per Building

The way to read previous table is:

- If we can inject -45 dBm/Hz, the maximum range per hop is 150m. This means that a building, which is 141m away from the transformer, will only require 1 repeater, while a building that is 201m away from the transformer will require 2 repeaters.
- If we can inject -55 dBm/Hz, the maximum range per hop is 125m. This means that a building, which is 121m away from the transformer, will only require 1 repeater, while a building that is 161m away from the transformer will require 2 repeaters.
- If we compute the "repeaters/building" figure for each distance and multiply by its probability coefficient (given by the Gaussian distribution), we get an average number of "repeaters per building":
  - A PSD of -50 dBm/Hz would get an average of 1.27 repeaters per building.
  - A PSD of -45 dBm/Hz would get an average of 1.154 repeaters per building.
  - A PSD of -60 dBm/Hz would get an average of 1.422 repeaters per building.

3.10 Effect of Service Competitiveness on Market Penetration

Utilities willing to use PLC for providing broadband Internet access must compete in an environment where other technologies (ADSL, cable, etc.) may be available. In that case, the service characteristics and the service price must remain competitive with the alternative, otherwise its market penetration will be negligible.

In this business document, a simple model has been built, where market penetration is a function of service speed (measured in Kbps) and service cost (measured in €/months). A reference of 40€ for a 512kbps connection has been used (based on ADSL offers currently available in Spain). With this price, a reference market penetration of 20% is assumed.

Market penetration is linear with service cost (with a negative slope) and with the logarithm of speed (with a positive slope).

$$Penetration = \frac{(60 - price) + 10 * \left(\log_2(speed) - 9\right)}{100}\%$$

This simplified model can be easily replaced with a more complex one by modifying the equation included in the Excel spreadsheet. For example, service penetration could be made dependent on the quality of the service provided to customers (SLA achievements) or on the availability of new applications enabled by IPv6 service.

3.11 Effect of IP Technology on Service Provisioning Costs

In this simplified model we have included three parameters that reflect the influence of which IP technology the operator is deploying:

- "Percentage of users with IPv6 enabled PCs": This number represents the percentage of customers who have a PC that can be potentially used with IPv6 (Windows XP and Linux), even if a download or service pack is required.
- "Service provisioning cost for non-IPv6 users": This parameter has already been described earlier in this document.

Other effects on the business model have not been included, but could be easily added to the spreadsheet:

- New revenue streams created by additional services enabled by IPv6.
- Increment in market share caused by additional services enabled by IPv6 or the IPv6 offering itself (even if not actually used by the customers).

4. FINANCIAL ANALYSIS

The financial analysis is basically focused on these steps:

- Compute the amount of equipment that needs to be installed each year for providing the service.
- Compute the amount of money spent on operational costs (Operations and Maintenance, Customer Support, Service Provisioning, Marketing).
- Compute the income for each year, taking into account that existing customers pay 12 months, while new customers pay an average of 6 months during their first year.
- Compute the net profit obtained each year, as:

  (profit)=(income)-(equipment cost)-(installation cost)-(operations costs)
- Compute the NPV (Net Present Value) of the yearly profits.

5. TECHNICAL ANALYSIS

5.1 Traffic Model

In order to estimate the requirements for bandwidth at the backbone and PLC networks, a traffic model is required. Different traffic models can provide different figures for peak bandwidth, average bandwidth, simultaneity figures, etc.

The model used in this analysis is based on a binomial distribution, which is useful for modeling groups of random variables which can be in either an “on” or “off” state with a given probability. In this model, we want to estimate the probability of “X” customers being simultaneously connected to the network (i.e., generating traffic) taking into account that each customer has a probability “Y” of being connected at any given time.

For example, let’s assume that we have **n** customers, and each customer has a probability **p** of being connected at any given time. Then, the probability that at any given time **k** customers are connected simultaneously is given by:

$$f_N(k) = \Pr\{N = k\} = \binom{n}{k} p^k (1-p)^{n-k}$$

If we use values (n=20, p=10%), then we get the following results for k=0,1,2,3,4,…

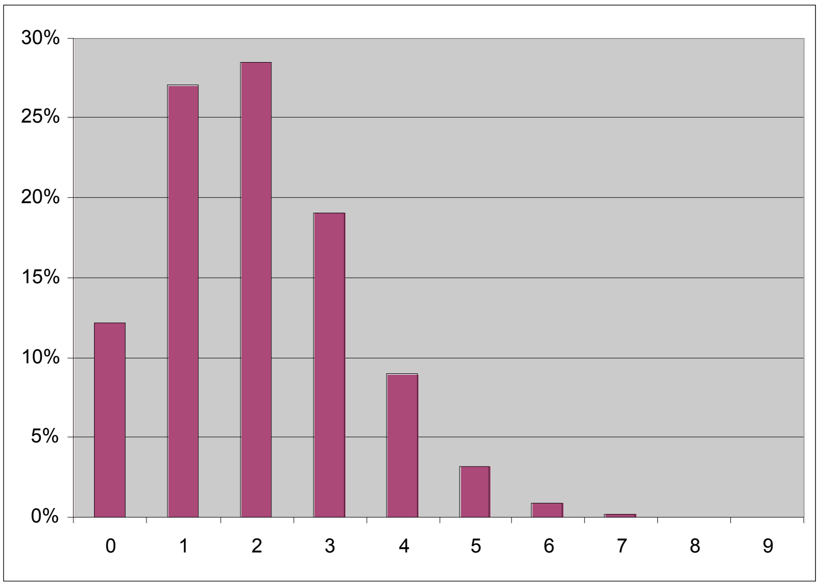
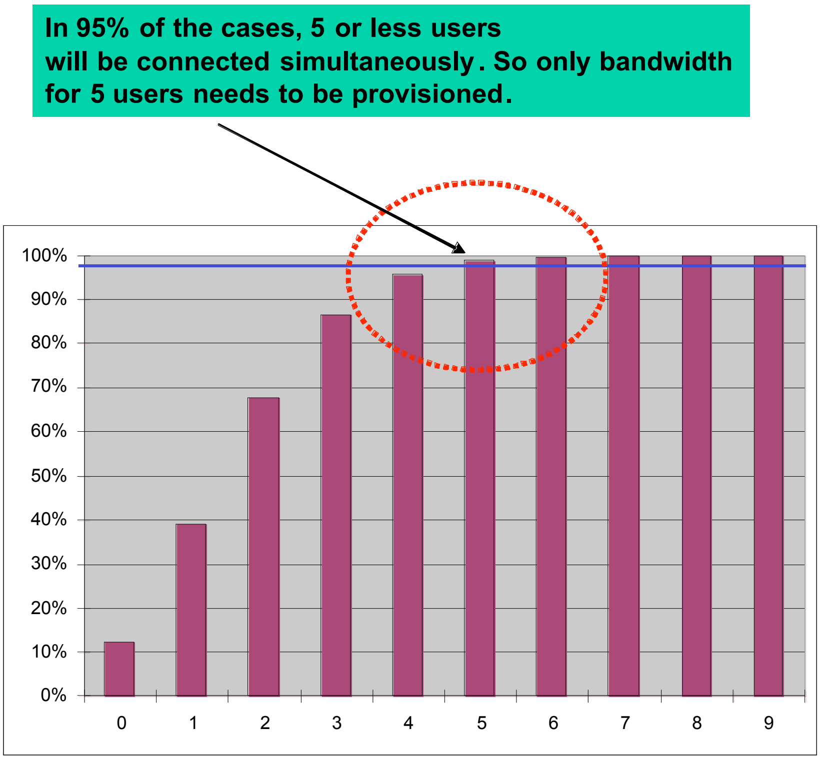


Figure 5-1: Probability of “k” Customers being Connected Simultaneously

The most probable value of k is 2, which makes sense, because on average 10% of our 20 customers will be connected, although in some cases, 3 or more customers will be connected, which also needs to be taken into account when designing the network.

Obviously, it does not make sense dimensioning the network for the case when 7 users will be connected, because this will happen with very low probability (less than 1%). As the following table shows, we can cover a high percentage of cases (95%) if we dimension the network for 5 customers or less.



In 95% of the cases, 5 or less users will be connected simultaneously. So only bandwidth for 5 users needs to be provisioned.

Figure 5-2: Probability of "k" or Less Customers being Connected Simultaneously

5.2 Effect of Incorrect Dimensioning on Network Performance

Correctly dimensioning network capacity is critical in order to provide a high-quality service to broadband customers. An under-dimensioned network will get saturated with high frequency, especially during periods of the day where a high number of users connect to the Internet. Users of a saturated network will experience high latency and high packet loss rate, which is a problem for real-time applications (like VoIP) and in a lower degree for interactive applications (like Web browsing), but probably not for the majority of peer-to-peer applications (like eMule, Kazaa, etc.), which represent a high percentage of the traffic in today's IP networks.

Dimensioning the network is an adaptive process (given that the usage pattern of the customers may change with time), so it is critical having updated information about real network usage. The following graphs show statistics from a MV link in a real power line network deployment that concentrates traffic from several transformers.

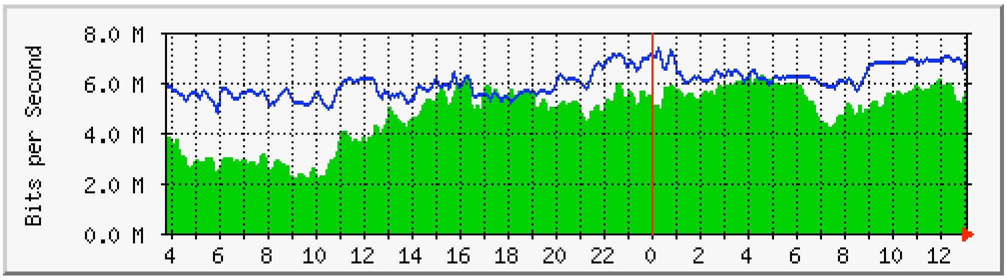


Figure 5-3: Traffic Statistics in a 24-Hour Period

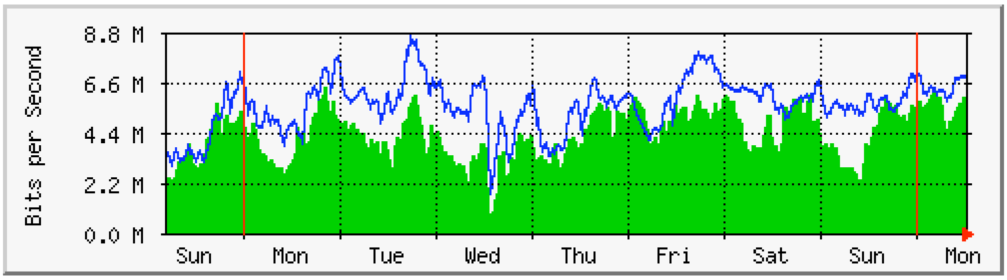


Figure 5-4: Traffic Statistics in a 1-Week Period

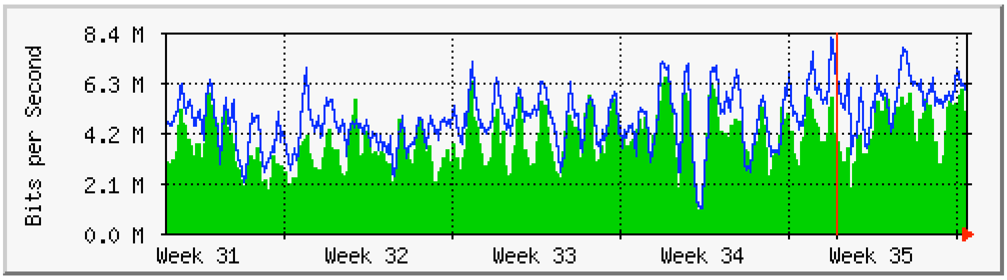


Figure 5-5: Traffic Statistics in a 1-Month Period

As previous graphs clearly show, traffic is not constant, and there is a cyclic behavior, with both a daily and weekly period. There are peaks usually during the evenings and at the beginning of the week.

Traffic peaks, if the network does not have enough capacity, can create saturation periods, which can be easily detected by an increment in network latency and packet loss rate, as the following graphs show.

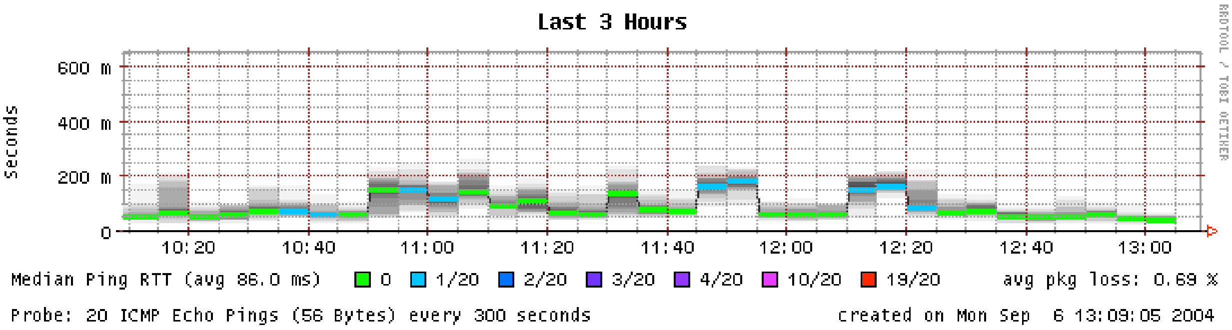


Figure 5-6: Latency and Packet Loss Rate Statistics, 3-Hour Period

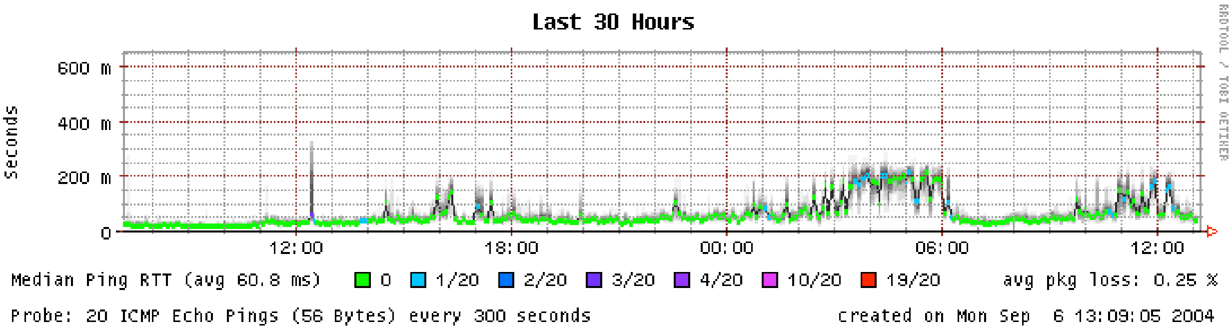


Figure 5-7: Latency and Packet Loss Rate Statistics, 30-Hour Period

Previous graph shows that the MV link under analysis has suffered long periods of saturation from 00:00 to 06:00 and from 09:30 to 13:00. There are also short periods of saturation scattered during the rest of the day. During these saturation periods, network latency increases from below 40ms to around 200ms. Packet loss rate increases also, from 0 to 1/20 (i.e. 5%) approximately (light blue color code).

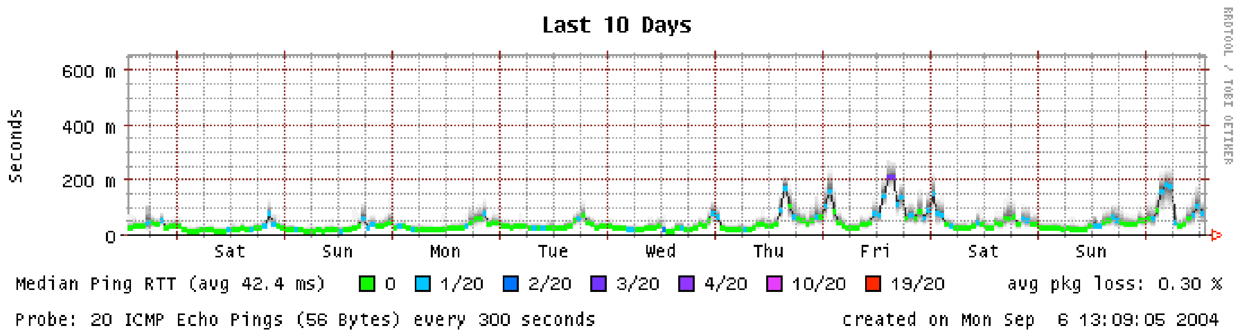


Figure 5-8: Latency and Packet Loss Rate Statistics, 10-Day Period

Previous graph shows that the saturation problem is not isolated, but is also happening almost every day, typically in short periods during the evening, although some days it happens more than once, and for longer periods.

This is a good example of a MV link which is clearly not capable of handling the amount of customers it is serving, and which cannot achieve the desired SLA figures.

5.3 Computing Traffic Requirements in the Spreadsheet Model

In this model, the technical analysis focuses on verifying that the network can provide the expected services. The process is as follows:

- At the "transformer level", compute the amount of bandwidth needed for satisfying the required SLA with the required QoS. Procedure:
  - Compute average number of residential users per transformer.
  - Compute aggregate bandwidth needed for satisfying customers' SLA, assuming that the random variable of simultaneous connections follows a binomial distribution.
- At the "MV PLC cluster level", compute the amount of bandwidth needed for satisfying the required SLA with the required QoS. The procedure is similar as the one described below, but the binomial distribution is calculated using the average number of customer per PLC-cluster instead of the average number of customer per transformer.
- Check the required bandwidth, with the available bandwidth (this is an input from the "equipment technical features" section).

5.4 Effect of Service Quality on Churn Rate

Another factor, which has also been included in the model is the effect of low service quality (caused by an under-dimensioned network which is often saturated) on customer churn rate. We have tried to simulate what happens when the network operator tries to sign more subscribers than the network can accept, and these customers later abandon the service due to bad connection quality.

We have assumed that churn rate can be modeled with non-linear function that has the following characteristics:

- When QoS is high (service is not saturated 100% of the time) there is a minimum residual churn rate of about 5% that cannot be reduced.
- As QoS is decreased (remaining above 90%), churn rate slowly increases up to 10%
- As QoS decreases below 90%, churn rate rapidly increases until it reaches 100% when QoS is 80%.

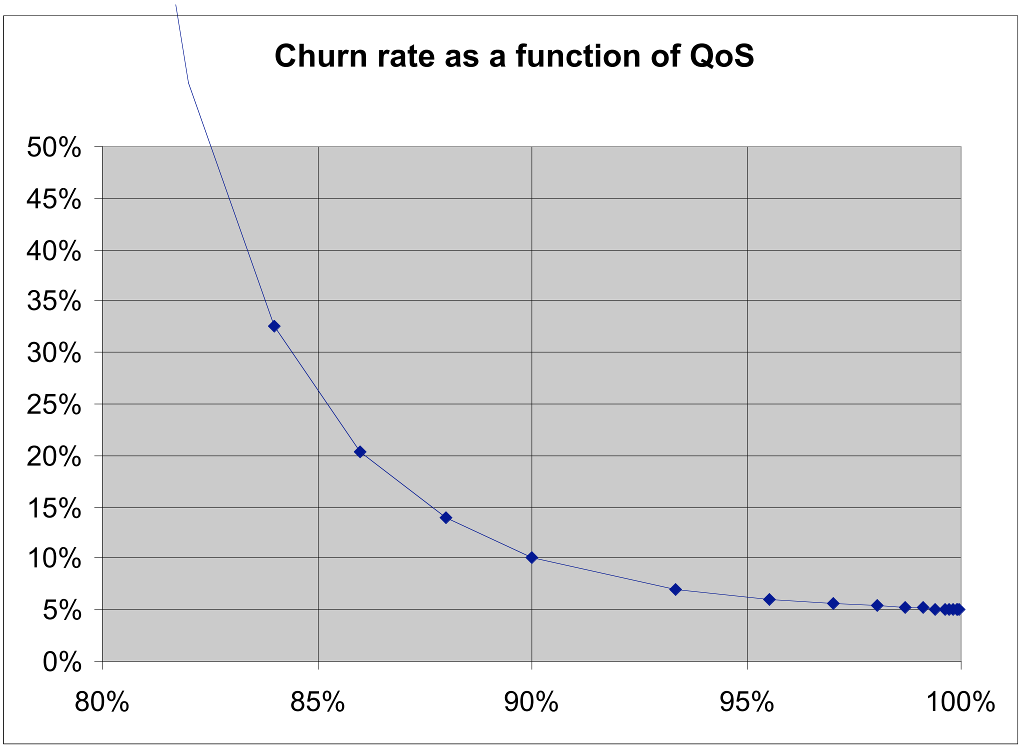


Figure 5-9: **Churn Rate as a Function of QoS**

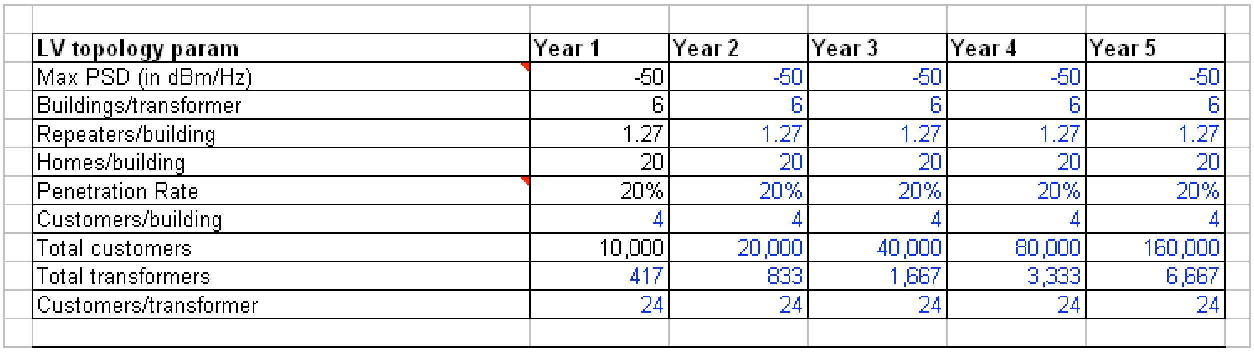
An increment in churn rate has a direct impact on business profitability, given that it artificially increases the number of CPEs and installations required in order to maintain a given number of customers.

6. SAMPLE SCENARIO

The figures provided in this section are example only, and should not be taken as a general model of a Power Line network. It should be customized for each specific network before the results can be considered valid.

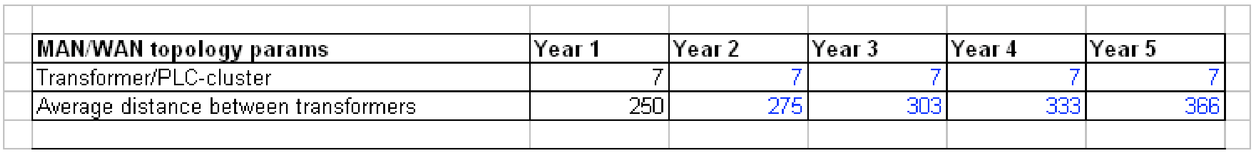
The scenario considered is based on the list of parameters shown in the next page. The more remarkable parameters are:

- Constant penetration rate of 20%, based on a service offered which is competitive with existing ADSL offers: 512kbps, with a monthly rate of 40€.
- Number of customers doubled every year (new areas are covered every year), starting from 10.000 on Year 1 and achieving 160.000 on Year 5.
- Cost of CPE is € 200 the first year and has a 40% of decrease every year because of economies of scale.
- PSD allowed by regulation: -50 dBm/Hz, which provides an average of 1.238 repeaters per building (i.e., one out of five buildings need an extra repeater).



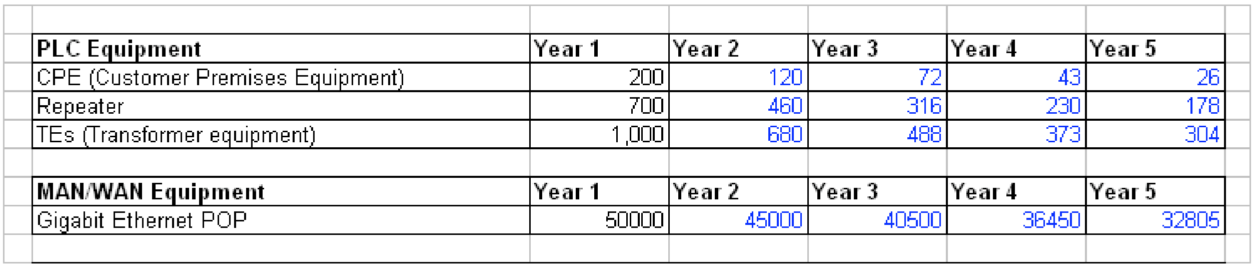
LV topology param	Year 1	Year 2	Year 3	Year 4	Year 5
Max PSD (in dBm/Hz)	-50	-50	-50	-50	-50
Buildings/transformer	6	6	6	6	6
Repeaters/building	1.27	1.27	1.27	1.27	1.27
Homes/building	20	20	20	20	20
Penetration Rate	20%	20%	20%	20%	20%
Customers/building	4	4	4	4	4
Total customers	10,000	20,000	40,000	80,000	160,000
Total transformers	417	833	1,667	3,333	6,667
Customers/transformer	24	24	24	24	24

Figure 6-1: Model Inputs – LV Topology Parameters



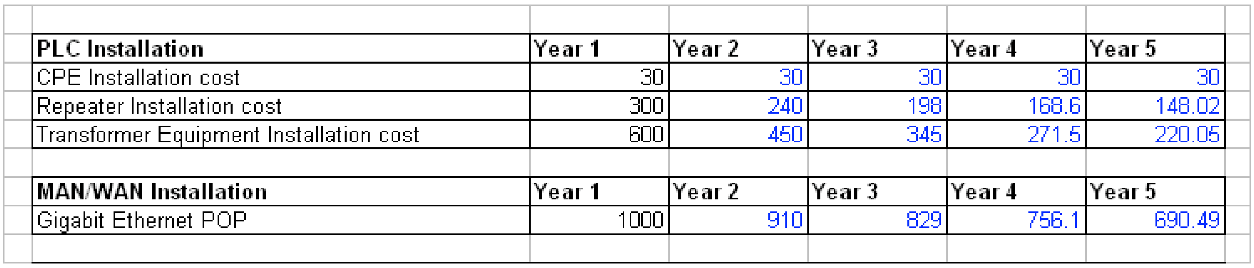
MAN/WAN topology params	Year 1	Year 2	Year 3	Year 4	Year 5
Transformer/PLC-cluster	7	7	7	7	7
Average distance between transformers	250	275	303	333	366

Figure 6-2: Model Inputs – MAN/WAN Topology Parameters



PLC Equipment	Year 1	Year 2	Year 3	Year 4	Year 5
CPE (Customer Premises Equipment)	200	120	72	43	26
Repeater	700	460	316	230	178
TEs (Transformer equipment)	1,000	680	488	373	304
MAN/WAN Equipment	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**
Gigabit Ethernet POP	50000	45000	40500	36450	32805

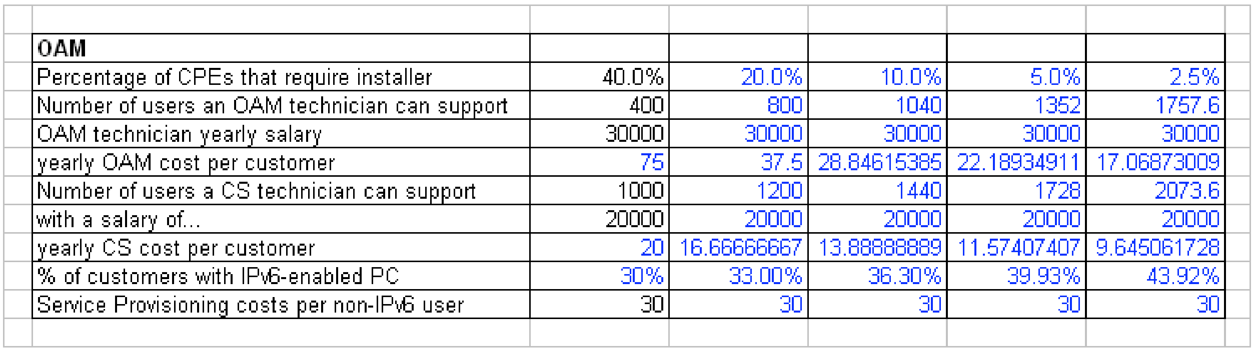
Figure 6-3: Model Inputs – Equipment Costs



PLC Installation	Year 1	Year 2	Year 3	Year 4	Year 5
CPE Installation cost	30	30	30	30	30
Repeater Installation cost	300	240	198	168.6	148.02
Transformer Equipment Installation cost	600	450	345	271.5	220.05

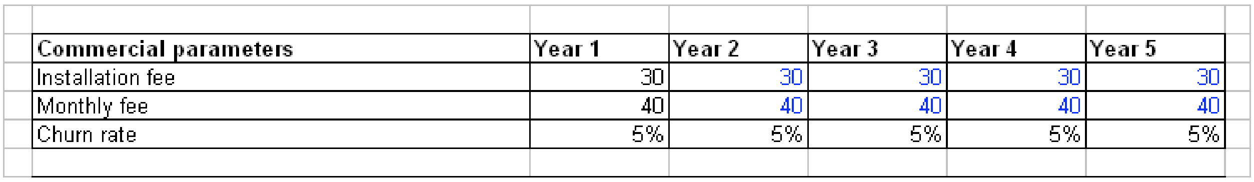
MAN/WAN Installation	Year 1	Year 2	Year 3	Year 4	Year 5
Gigabit Ethernet POP	1000	910	829	756.1	690.49

Figure 6-4: Model Inputs – Installation Costs



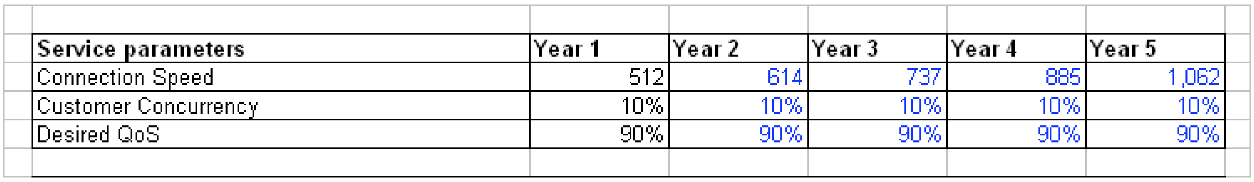
OAM					
Percentage of CPEs that require installer	40.0%	20.0%	10.0%	5.0%	2.5%
Number of users an OAM technician can support	400	800	1040	1352	1757.6
OAM technician yearly salary	30000	30000	30000	30000	30000
yearly OAM cost per customer	75	37.5	28.84615385	22.18934911	17.06873009
Number of users a CS technician can support	1000	1200	1440	1728	2073.6
with a salary of...	20000	20000	20000	20000	20000
yearly CS cost per customer	20	16.66666667	13.88888889	11.57407407	9.645061728
% of customers with IPv6-enabled PC	30%	33.00%	36.30%	39.93%	43.92%
Service Provisioning costs per non-IPv6 user	30	30	30	30	30

Figure 6-5: Model Inputs – Operations & Maintenance Costs



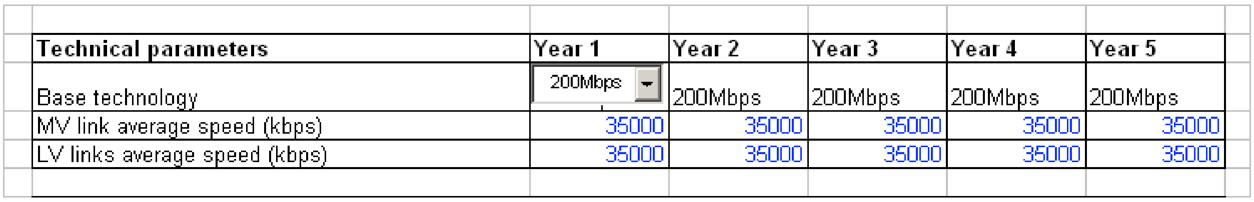
Commercial parameters	Year 1	Year 2	Year 3	Year 4	Year 5
Installation fee	30	30	30	30	30
Monthly fee	40	40	40	40	40
Churn rate	5%	5%	5%	5%	5%

Figure 6-6: Model Inputs – Commercial Parameters



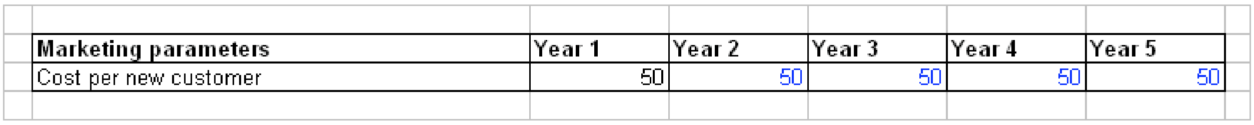
Service parameters	Year 1	Year 2	Year 3	Year 4	Year 5
Connection Speed	512	614	737	885	1,062
Customer Concurrency	10%	10%	10%	10%	10%
Desired QoS	90%	90%	90%	90%	90%

Figure 6-7: Model Inputs – Service Parameters



Technical parameters	Year 1	Year 2	Year 3	Year 4	Year 5
Base technology	200Mbps	200Mbps	200Mbps	200Mbps	200Mbps
MV link average speed (kbps)	35000	35000	35000	35000	35000
LV links average speed (kbps)	35000	35000	35000	35000	35000

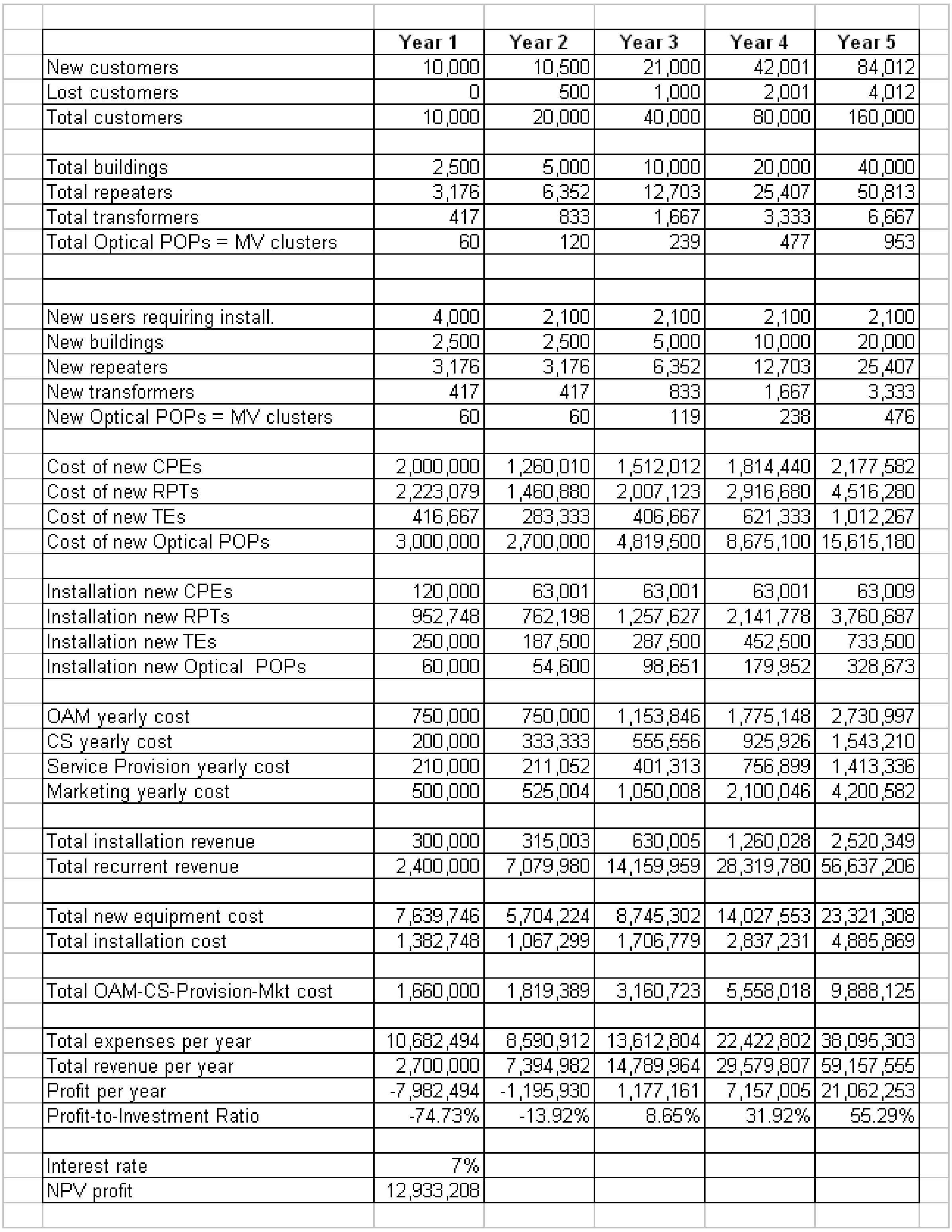
Figure 6-8: Model Inputs – PLC Technology Parameters



Marketing parameters	Year 1	Year 2	Year 3	Year 4	Year 5
Cost per new customer	50	50	50	50	50

Figure 6-9: Model Inputs – Marketing costs Parameters

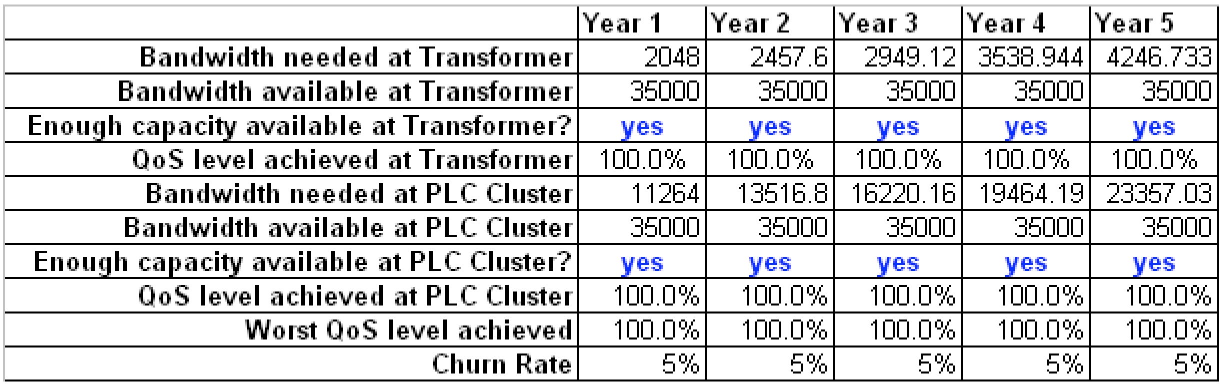
The financial results are shown in the next table:



	Year 1	Year 2	Year 3	Year 4	Year 5
New customers	10,000	10,500	21,000	42,001	84,012
Lost customers	0	500	1,000	2,001	4,012
Total customers	10,000	20,000	40,000	80,000	160,000
Total buildings	2,500	5,000	10,000	20,000	40,000
Total repeaters	3,176	6,352	12,703	25,407	50,813
Total transformers	417	833	1,667	3,333	6,667
Total Optical POPs = MV clusters	60	120	239	477	953
New users requiring install.	4,000	2,100	2,100	2,100	2,100
New buildings	2,500	2,500	5,000	10,000	20,000
New repeaters	3,176	3,176	6,352	12,703	25,407
New transformers	417	417	833	1,667	3,333
New Optical POPs = MV clusters	60	60	119	238	476
Cost of new CPEs	2,000,000	1,260,010	1,512,012	1,814,440	2,177,582
Cost of new RPTs	2,223,079	1,460,880	2,007,123	2,916,680	4,516,280
Cost of new TEs	416,667	283,333	406,667	621,333	1,012,267
Cost of new Optical POPs	3,000,000	2,700,000	4,819,500	8,675,100	15,615,180
Installation new CPEs	120,000	63,001	63,001	63,001	63,009
Installation new RPTs	952,748	762,198	1,257,627	2,141,778	3,760,687
Installation new TEs	250,000	187,500	287,500	452,500	733,500
Installation new Optical POPs	60,000	54,600	98,651	179,952	328,673
OAM yearly cost	750,000	750,000	1,153,846	1,775,148	2,730,997
CS yearly cost	200,000	333,333	555,556	925,926	1,543,210
Service Provision yearly cost	210,000	211,052	401,313	756,899	1,413,336
Marketing yearly cost	500,000	525,004	1,050,008	2,100,046	4,200,582
Total installation revenue	300,000	315,003	630,005	1,260,028	2,520,349
Total recurrent revenue	2,400,000	7,079,980	14,159,959	28,319,780	56,637,206
Total new equipment cost	7,639,746	5,704,224	8,745,302	14,027,553	23,321,308
Total installation cost	1,382,748	1,067,299	1,706,779	2,837,231	4,885,869
Total OAM-CS-Provision-Mkt cost	1,660,000	1,819,389	3,160,723	5,558,018	9,888,125
Total expenses per year	10,682,494	8,590,912	13,612,804	22,422,802	38,095,303
Total revenue per year	2,700,000	7,394,982	14,789,964	29,579,807	59,157,555
Profit per year	-7,982,494	-1,195,930	1,177,161	7,157,005	21,062,253
Profit-to-Investment Ratio	-74.73%	-13.92%	8.65%	31.92%	55.29%
Interest rate	7%				
NPV profit	12,933,208				

Figure 6-10: Financial Analysis

Next Figure includes the “technical outputs” (which show that, with current model parameters, the system will be able to satisfy the QoS/SLAs during the whole period under study, thus keeping churn rate at the minimum level of 5%).



	Year 1	Year 2	Year 3	Year 4	Year 5
Bandwidth needed at Transformer	2048	2457.6	2949.12	3538.944	4246.733
Bandwidth available at Transformer	35000	35000	35000	35000	35000
Enough capacity available at Transformer?	yes	yes	yes	yes	yes
QoS level achieved at Transformer	100.0%	100.0%	100.0%	100.0%	100.0%
Bandwidth needed at PLC Cluster	11264	13516.8	16220.16	19464.19	23357.03
Bandwidth available at PLC Cluster	35000	35000	35000	35000	35000
Enough capacity available at PLC Cluster?	yes	yes	yes	yes	yes
QoS level achieved at PLC Cluster	100.0%	100.0%	100.0%	100.0%	100.0%
Worst QoS level achieved	100.0%	100.0%	100.0%	100.0%	100.0%
Churn Rate	5%	5%	5%	5%	5%

Figure 6-11: Technical Analysis

The following graphs show the main economic figures:

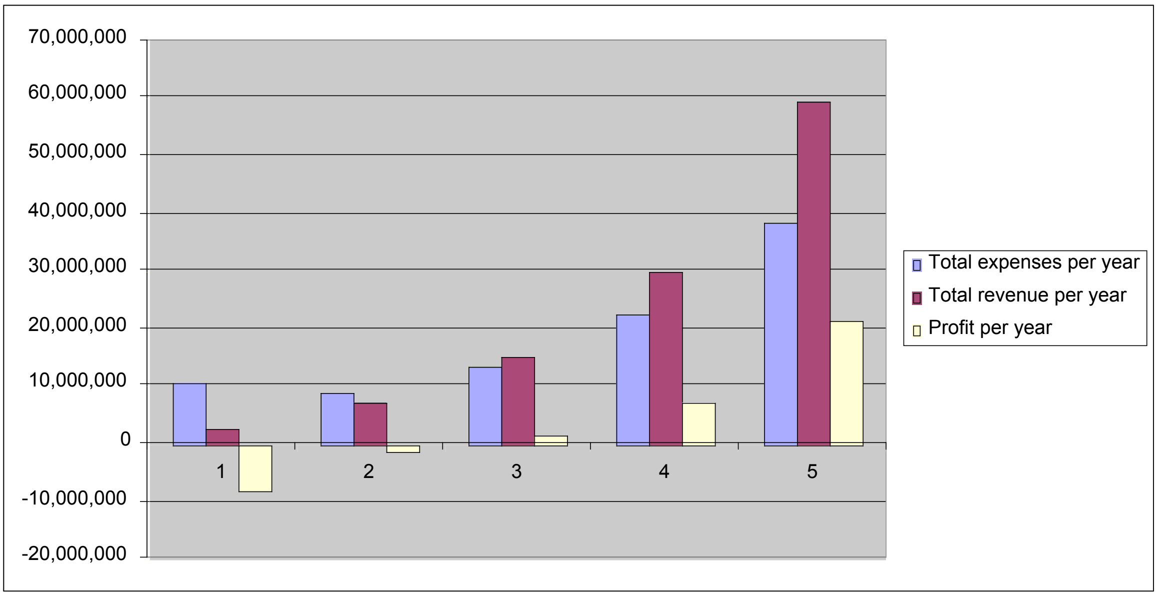


Figure 6-12: Evolution of Expenses, Revenues and Profit

As can be seen, profits are only obtained since Year 3, once a significant number of new users start to make use of the backbone equipment installed on Years 1 and 2.

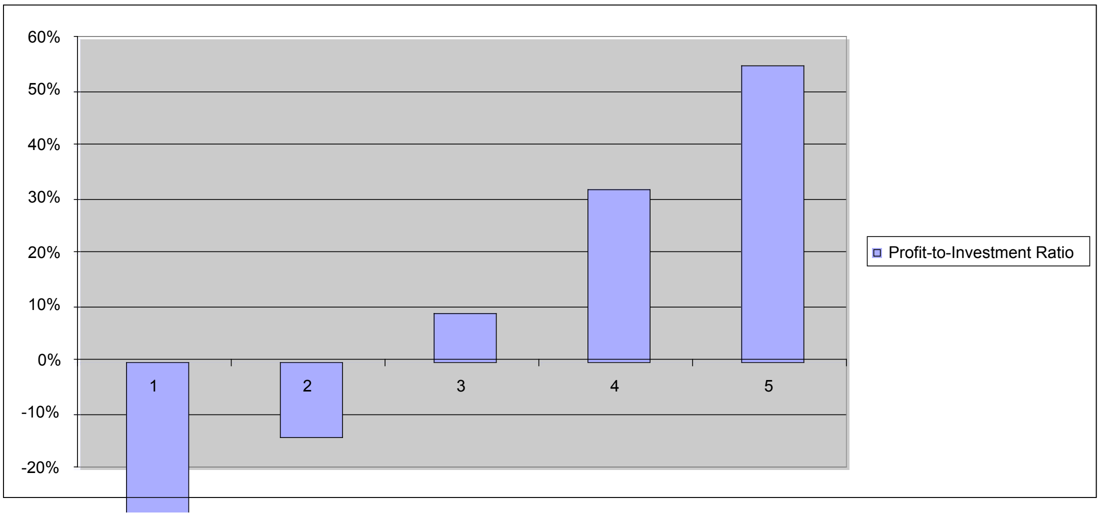


Figure 6-13: Evolution of Yearly Profit-to-Investment Ratio

Equipment costs, as expected, are dominated by CPE costs, which is the device with the higher volume.

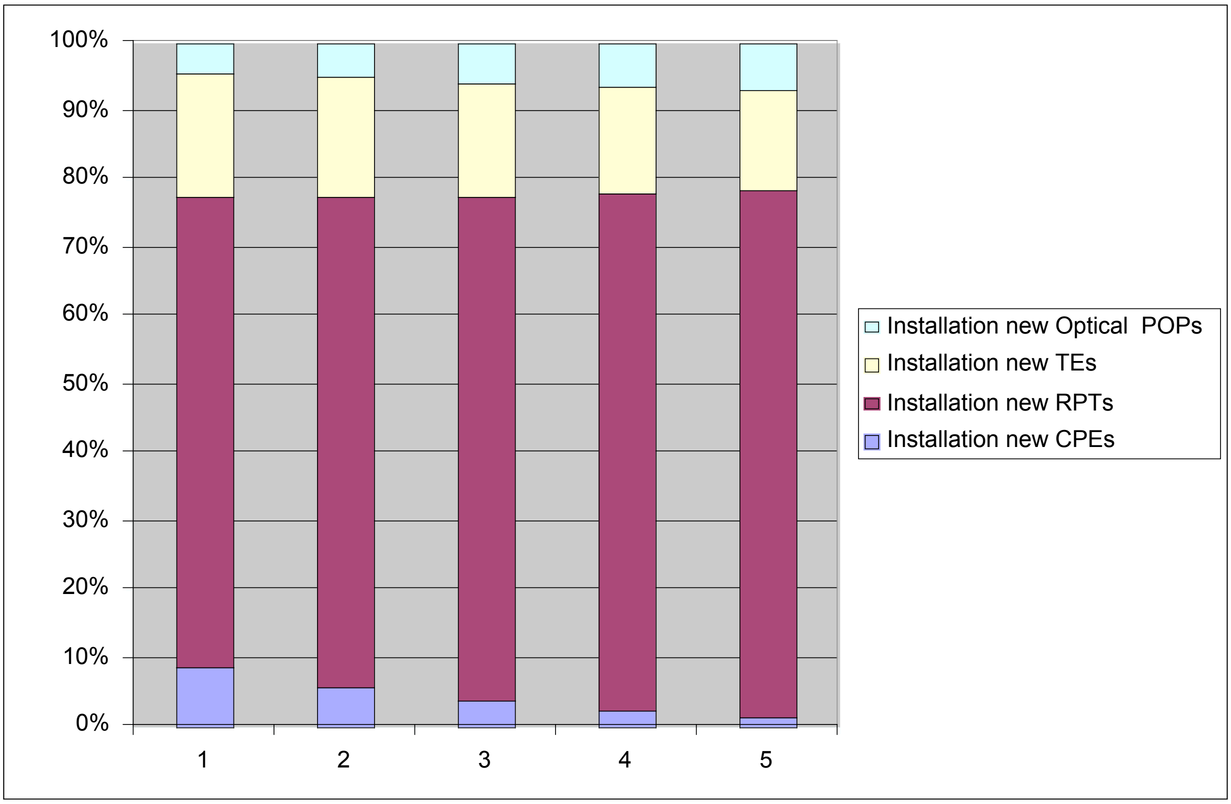


Figure 6-14: Distribution of Installation Costs

Installation costs are always dominated by optical fiber installation costs. As installation of PLC equipment gets easier each year, the cost of optical fiber installation gets an even bigger share of the costs.

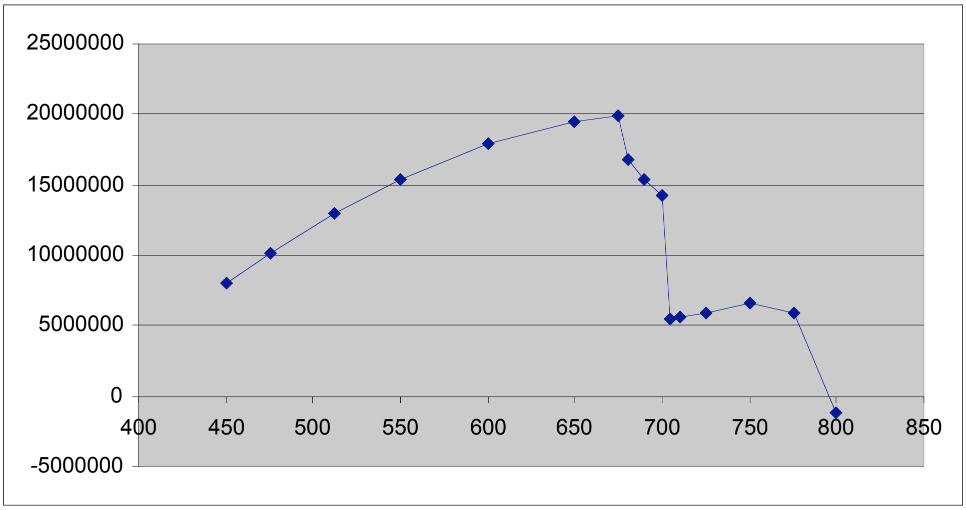


Figure 6-15: Dependency of NPV on Connection Speed

Figure 6-15 show how sensible is the model to variations in the connection speed. Under the assumptions of this model, service penetration increases slowly as connection speed increases from 450 kbps to about 650 kbps (as the service increases its competitiveness against other broadband offerings). An important effect happens when connection speed is increased beyond a certain point: Too much speed can saturate the network, reduce end-user QoS and increase churn rate, which has a strong effect on financial results.

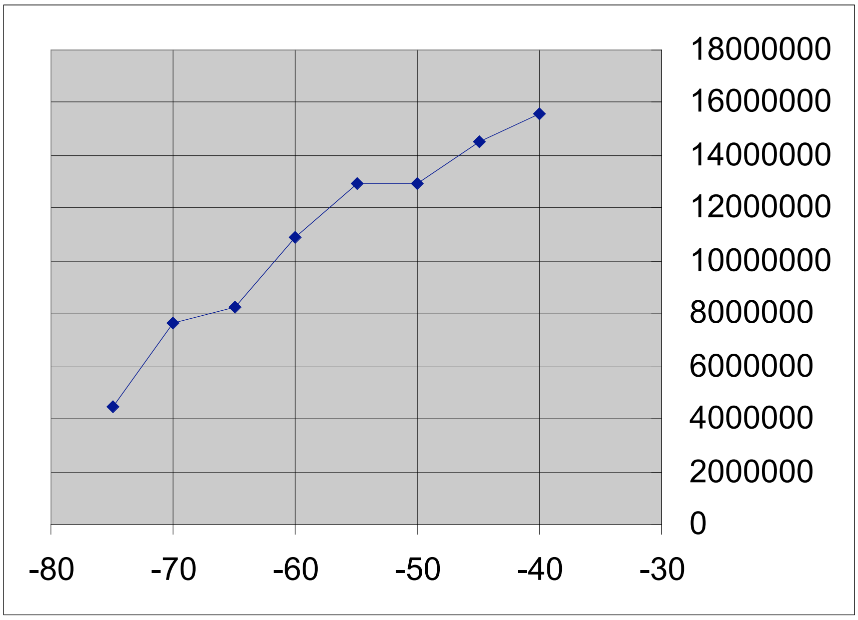


Figure 6-16: Dependency of NPV on Maximum Allowed PSD

Figure 6-16 shows how sensible is the model to variations in maximum PSD allowed by EMC regulations. Obviously, as the maximum PSD is reduced from the reference value of -50 dBm/Hz, the increment in the number of repeaters required makes the business less attractive to utilities.

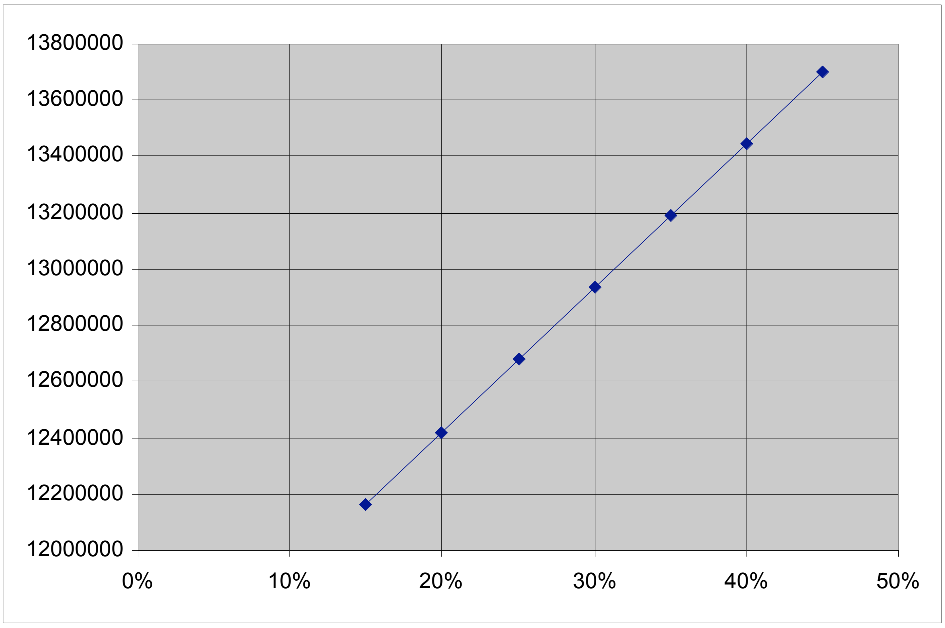


Figure 6-17: Dependency of NPV on Percentage of IPv6-enabled Customers

Figure 6-16 shows how sensible is the model to variations in the percentage of customers with an IPv6-enabled PC. The higher this number is, the lower the costs of IP provisioning to the operator. The effect is not dramatically strong, but can easily justify the cost of doing the transition of the network from IPv4 to IPv6.

7. SUMMARY AND CONCLUSIONS

The business model developed in the 6POWER project provides a powerful and easy-to-use tool for estimating the main numbers involved in the design of a power line access network.

It can be used for several purposes:

- Selecting which areas should be deployed first. Usually it will be those with an expected penetration rate, which is high enough, or those with the appropriate number of buildings per transformer, for example.
- Preparing marketing strategies (target customers, SLAs characteristics, expected QoS levels, etc.).
- Selecting technologies (should you use a low-speed, low-price technology, or a faster, more-expensive technology?).

All the combinations will depend also in the market in the target area, for example competitors with PLC or other technologies and so on.

The numbers provided in this document are example only, as should not be taken as a general model of a Power Line network. It should be customized for each specific city before the results can be considered valid.

Is also important recognize that the cost of the network could be lower in those cases where fiber or other technologies are already available in the different rings, WAN POP, etc.

Finally, the usage of IPv6 could lower the cost, considering the autoconfiguration features, but at this stage is difficult to consider the exact and precise cost because the lack of large scale commercial deployments which provide public, detailed and realistic information. Nevertheless, recent studies suggest installation and management cost 30-35% lower than the same networks with IPv4.