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Dynamic Total Cost of Ownership Optimization for IPTV Service Deployment

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Abstract: The Total Cost of Ownership (TCO) for developing communication services comprises from two parts; CAPital EXpenditure (CAPEX) and OPerational EXpenditure (OPEX). These two types of costs are interrelated and affect any service provider's deployment strategy. In many traditional methods, selection of critical elements of a new service is performed in a heuristic manner aimed at reducing only the OPEX part of the TCO which is not necessarily optimal. In the current study, a mathematical modeling approach is developed for describing the cost of each Internet Protocol Tele Vision (IPTV) component. Then, based on the proposed models, the TCO optimization problem of the IPTV service is formulated as a nonlinear programming one. The solution of the proposed optimization problem can track the dynamic changes of the TCO and lead to a time-varying optimal solution. Numerical results associated with the developed method are presented.

Key words: TCO, OPEX, CAPEX, IPTV

INTRODUCTION

IPTV uses IP as the transport platform to send video signals to the television via high-speed Internet connections such as fiber-to-the-X connections (FTTx) and/or next-generation digital subscriber lines (xDSL). With this technology, consumers will be in complete control of what, when and where they watch television programming. Moreover, given the versatility of the IP network, consumers will have the opportunity to embrace a plethora of services that go beyond video signals.

Service providers and/operators have to minimize CAPEX and OPEX, achieve on time service launch, deliver quality of service that will drive service adoption and define an architecture that provides upward scalability for size and services (Clarke ans Anandalingam, 1996). A service provider considering the delivery of an IPTV service should consider the TCO when assessing the merits of different service delivery approaches.

TCO is a financial estimate designed to help consumers and enterprise managers assess direct and indirect costs commonly related to software or hardware. It is a form of full cost accounting.

Middleware and other systems needed to provide video are also part of the total CAPEX. In a business case, CAPEX can be broken into fixed and variable parts; fixed being those costs to build the requisite system and infrastructure to deliver the services and variable being those costs incurred with individual subscriber take rates. Consumer Premises Equipment (CPE) and in home installation are considered variable costs, along with DSL line cards, since the CAPEX is incurred only when service is taken. Ideally, fixed CAPEX should be minimized since it is the at risk investment to enter into the business. Variable CAPEX, although directly related to actual service take rate and revenue, cannot be so excessive as to present a Return On Investment (ROI) that it creates unacceptable ROI.

IPTV business cases as well as actual deployments have shown that the in home CPE and installation costs amount to 60% or more of the total installed cost for the IPTV system (Thomson, 2007).

With CPE and in-home installation representing the largest portion of total installed cost, it is the area best targeted for cost reduction.

OPEX is composed of funds used by a company to acquire or upgrade physical assets such as property, industrial buildings or equipment.

This type of outlay is made by companies to maintain or increase the scope of their operation. These expenditures include everything from repairing a roof to building a brand new factory.

Video-on-Demand (VoD) is the next killer-app and a subset of the IPTV service. Initial trials have been well received by customers and network operators are deploying VoD to increase subscriber revenues and service profitability. VoD allows subscribers to request the programming of their choice, when they want where they want it. It is this flexibility that appeals to the broader customer base when compared with regularly scheduled network programming of broadcast video.

In most traditional methods, the only objective is to minimize the OPEX part of the TCO by selecting critical components of the service in a heuristic manner. But, this approach may not necessarily result in optimal solution for the service providers.

For example, in deploying the IPTV service in Iran, the service providers select the number of the required edge servers (IBM) in order to minimize the OPEX part of the TCO.

Because of its static nature, this method doesn't consider the interrelations between OPEX and CAPEX which varies with time. For example, though choosing a specific initial number of edge servers may be optimal at the first stages of service deployment, this may not lead to an optimal solution for TCO minimization problem as time elapses.

Any solution for minimizing the TCO must take into the account the dynamic characteristics of the problem as time elapses.

In the current study, a mathematical approach is developed to minimize the TCO. The proposed method tracks the dynamic changes in the number of subscribers and takes into the account the subscribers' geographical distributions and time.

At first the problem is formulated using appropriate models for CAPEX and OPEX parts of each IPTV element, then, using appropriate numerical methods (Luenberger, 1984), a cost optimization strategy is developed.

Total cost of ownership modeling is a tool that systematically accounts for all costs related to an IT investment decision. TCO models were initially developed by Gartner Research Corporation in 1987 and are now widely accepted. Simply stated, TCO includes all costs, direct and indirect, incurred throughout the life cycle of an asset, including acquisition and procurement, operations and maintenance and end-of-life management.

TCO analysis originated with the Gartner group in 1987 and has since been developed in a number of different methodologies and software tools. A TCO assessment ideally offers a final statement reflecting not only the cost of purchase but all aspects in the further use and maintenance of the equipment, device, or system considered. This includes the costs of training support personnel and the users of the system, costs associated with failure or outage (planned and unplanned), diminished performance incidents (i.e., if users are kept waiting), costs of security breaches (in loss of reputation and recovery costs), costs of disaster preparedness and recovery, floor space, electricity, development expenses, testing infrastructure and expenses, quality assurance, boot image control, marginal incremental growth, decommissioning, e-waste handling and more.

When incorporated in any financial benefit analysis TCO provides a cost basis for determining the economic value of that investment.

The TCO concept is widely used in the automobile industry. In this context, the TCO denotes the cost of owning a vehicle from the purchase, through its maintenance and finally its sale as a used car. Comparative TCO studies between various models help consumers choose a car to fit their needs and budget. After extensive market research in Iran, estimation about the CAPEX and OPEX of each IPTV component is derived from which a mathematical model has been developed for the TCO of IPTV service (Heigden *et al*., 2004).

IPTV SERVICE

IPTV describes a system where a digital television service is delivered using over an IP-based network infrastructure, which may include delivery by a broadband connection (Ardagna *et al*., 2008) and (ITU).

For residential users, IPTV is often provided in conjunction with VoD and may be bundled with Internet services such as Web access and Voice over IP (VoIP). The commercial bundling of IPTV, VoIP and Internet access is referred to as a Triple Play. Adding the mobile voice service leads to the Quadruple Play denomination.

IPTV is typically supplied by a broadband operator using a closed network infrastructure. This closed network approach is in competition with the delivery of TV content over the public Internet. This type of delivery is widely called TV over Internet or Internet Television.

In businesses, IPTV may be used to deliver television content over corporate LANs and business networks. Perhaps a simpler definition of IPTV would be television content that, instead of being delivered through traditional formats and cabling, is received by the viewer through the technologies used for computer networks.

Broadcast IPTV has two major architecture forms: free and fee based. This sector is growing rapidly and major television broadcasters worldwide are transmitting their broadcast signal over the Internet. IPTV channels require only an Internet connection and an Internet enabled device such as a personal computer, iPod, High Definition Tele Vision (HDTV) connected to a computer or even a 3G cell/mobile phone to watch the IPTV broadcasts. A typical IPTV scenario is shown in the Fig. 1.

The basic components of IPTV service are, video streaming servers (Ardagna, 2002 and ISMA) for streaming the video content, edge streaming servers used for load balancing purposes, encoded content, transport and access Quality of Service (QoS)-enabled networks (Abdelzaher *et al*., 2003), BRAS (Broadband Remote Access Server) for traffic routing, policy management and QoS implementation, DSLAM (Digital Subscriber Line Access Multiplexer) for access users' traffic aggregation,

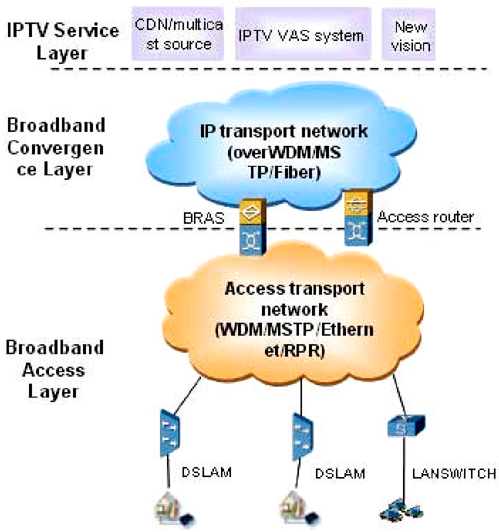

Fig. 1: Typical IPTV service scenario

STB (Set Top Box) for TV interface, Content Distribution Network (CDN) for high performance media distribution and ADSL (Asymmetric DSL) modems for having a high-speed Internet connection (Berman and Vasudeva, 2005).

Each IPTV component is associated with an incurred CAPEX and OPEX. Some components such as transport network are out of the service provider's control and impose only a long-term OPEX on the service provider's deployment strategy and some of the components such as content only consist of an initial CAPEX and do not impose any important OPEX on the service development.

Here, Mathematical models for the CAPEX and OPEX of each IPTV component are developed and based on the proposed models; a dynamic solution for the TCO minimization problem is introduced.

LOOKING AT IPTV TOTAL COST OF OWNERSHIP

There are two approaches to assess the total cost of ownership for an IPTV service:

- A heterogeneous approach, in which multiple vendors provide different components of the solution, often with one or more systems integrators providing the services that bind these heterogeneous solutions into a single service delivery solution. In this approach, operations management is typically layered on top of the service delivery system after the fact. Most of the current IPTV deployments to date adopt this approach
- A homogenous approach, in which a single solutions vendor designs, builds, tests, validates and supports the IPTV service delivery and operations management solution
- The total cost of ownership associated with an IPTV service depends on a variety of factors, including
- Capital expenditure (CAPEX) for the service delivery hardware, software and network infrastructure
- Operating expenditure (OPEX) for the development, ongoing delivery and maintenance of the service delivery infrastructure

Some of the OPEX will be start-up costs, such as those associated with initial deployment and those related to the integration of the IPTV infrastructure with existing Business Support Systems (BSS) and Operations Support Systems (OSS) (Sathyan, 2009). Other OPEX are ongoing, including the expense of day-to-day monitoring and managing of the infrastructure. Still other OPEX will arise as the result of decisions to evolve the service delivery network. These expenses can be seen as project related expenses, but decisions taken upfront about how the service provider will deliver the IPTV service can lead to higher operations costs and projects that are more complex when it is time to upgrade the service delivery network.

These downstream costs must be factored into the TCO equation. In addition to CAPEX and OPEX, service providers can encounter costs associated with content acquisition.

These costs can vary based on revenue opportunities a service provider can offer a content provider. Typically, the content costs are based on the number of subscribers. However, the expanded service delivery opportunities afforded by IPTV may change this. If, for example, the IPTV service offers subscribers a chance to select alternate camera feeds from a sporting event, the content provider that owns these feeds may charge a higher fee for content than it would if subscribers were unable to switch between camera feeds on their own. Therefore, there may be some variations in pricing for content delivered over IPTV.

However, because it is anticipated that service providers will pass along this type of additional content fees in the form of higher subscription fees, the net effect of any content cost variations upon TCO will be negligible. Consequently, content costs are not a critical component in the calculation of TCO for the purpose of this study. Infrastructure costs to offer IPTV as a subscriber-oriented service requires investment in a platform to deliver and manage the service.

The service provider must acquire systems for encoding and delivering live content as well as systems for encoding, storing and delivering VoD content.

The service provider must deploy systems to manage this content and its delivery; it must also deploy systems to monitor and maintain the network, the content delivery and the management systems themselves and that is just a high-level description of a central head-end installation. There are multiple metro head-end configurations to deploy and these involve local content delivery servers, local VOD servers, local management servers and more. TCO for such a network infrastructure depend in part on the service delivery approach that the provider selects. A service provider, as previously explained, can choose between homogenous or heterogeneous approaches.

After many years of building voice networks, the heterogeneous approach may be familiar to telecommunication companies. It offers certain attractions, because it enables a service provider to build a service delivery solution based on best of breed components that may have been fine-tuned for the delivery of IPTV. At the same time, telecommunication companies are familiar with the downside of this approach: because best of breed products are so precisely focused on doing one thing well, they are often built on specialized or proprietary architectures that are costly to acquire and support.

Moreover, individual component vendors are unlikely to have built their products to interact with precisely the collection of components in a given heterogeneous service delivery configuration; there are simply too many possible configurations and variations. Because no single solutions vendor has tested and validated the entire solution prior to the service provider's acquisition of these separate components, the creation of a heterogeneous solution requires a costly and time-consuming systems integration and testing effort.

Operations and maintenance costs total cost of ownership involves more than the cost of deploying the hardware and software associated with the core service delivery platform. The annual cost, fully loaded, of a well qualified support technician, recurring OPEX costs can be among the most important to consider when calculating TCO.

Reducing TCO requires an approach to IPTV that enables a small operations management team to work efficiently.

If the service provider chooses the heterogeneous systems approach, OPEX costs may be much higher than if the service provider chooses a homogenous systems approach. There are two key reasons why this is true.

Because the individual components in a heterogeneous solution are typically specialized or proprietary, they typically require the attention of support personnel with specialized training and experience who typically command higher salaries in the marketplace.

Moreover, because operations management in the heterogeneous approach is typically layered on top of the solution as an afterthought, the operations management component may not be able to provide the levels of automation and efficiency that would enable the service provider to support a large distributed network with a lean operations team. An approach to operations and maintenance that enables a service provider to rely on a leaner and less costly support staff can have a dramatic impact on TCO.

Solutions that rely on standards-based commodity hardware involve lower CAPEX than proprietary technologies.

- Homogenous solutions typically lower day-to-day IPTV OPEX because they makes the most of automation, provide end-to-end monitoring and management capabilities and rely on easily obtainable professional skills
- Complete, fully architected, packages can lower cost and risk

The providers of homogenous solutions have done the work to define and design the solution, enabling the service provider to deploy it to subscribers and have it begin generating revenue in a matter of days, not months.

Moreover, with a complete package that includes professional support services, the service provider always knows where to go if it has a question.

In a heterogeneous service delivery environment, there is no single resource for all the service provider's support needs and no single entity to architect and validate the solution on an ongoing basis. As a provider's IPTV service needs and opportunities evolve over time, the developers of homogenous packages can make the changes easier and less costly. They can anticipate how a service provider can evolve service delivery and prepare best practices guidelines in advance to help the service provider transform its service delivery infrastructure.

With the solution provider acting to validate the entire service delivery environment, the service provider can be confident that when an update or enhancement is made to the solution, every part of the solution that could be affected by the change has been tested and validated already.

Ultimately, a service provider's goal is to deliver a competitive service that can help it increase its revenues and subscriber base at the lowest possible cost. With a comprehensive architecture and guidelines, integrated systems management services and flexible deployment options, homogenous, complete, IPTV solutions can be designed to help the service provider meet their goals.

PROBLEM FORMULATION AND MODELING

It must be mentioned that in the current study, we only consider the homogenous approach for assessing the TCO of the IPTV service because it is a good match for the IPTV developers' strategy in Iran.

In order to minimize the TCO (CAPEX+OPEX) of an IPTV service, the mathematical models associated with the CAPEX and OPEX of each component which is involved in the service have been developed in a theoretical manner.

In practice, development of a comprehensive model for minimizing the total cost of ownership of an IPTV service is very difficult. Here, we ignore some parameters described in above to make the mathematical modeling possible.

DSLAM, STB, ADSL modem, Edge server, Main server are among the devices which together build an IPTV solution. Here, mathematical models for CAPEX and OPEX of these components are presented. To do so, we first make an estimation of the initial cost of each component individually based on the research accomplished in Iran's IPTV market (TIA). The initial cost of STB, ADSL modem, DSLAM, BRAS, main server, edge server, content and infrastructure are denoted by x_{STB}, x_{MDM}, x_{DSLM}, x_{MSRVR}, x_{ESRVR}, x_{CNT} and x_{INSTR}, respectively.

Table 1 shows the initial cost of the devices normalized by the initial cost of ADSL modem.

It must be mentioned that the above normalized values in Table 1 are obtained from a survey on the prices of each IPTV component which was investigated about the Iran's IT market.

In order to capture the dynamic nature of the mentioned components of the TCO, the mathematical models for CAPEX and OPEX are chosen to be functions of time t, No. of subscribers n and No. of edge servers m.

It must be mentioned that except the CAPEX associated with the content (which assumed to be fix) and the CAPEX associated with the network infrastructure (which assumed to be null), all of the CAPEX formulations are in accordance with the power-law/exponential distributions for the cost estimation method and the inflation effect (Aoki and Yoshikawa, 2006).

Hence, the CAPEX associated with most of the IPTV components is a decreasing function of the number of subscribers n and an increasing function of time t because it is assumed that the CAPEX can be reduced as the demand n increases and can be increased for the sake of inflation as time t elapses.

It is assumed that there exist 2 main servers (original+backup) for the sake of high availability purposes (Sadowsky *et al*., 2003).

Table 1: Initial cost of IPTV devices normalized by ADSL modem cost

Device	Cost
x_{STB}	3.33
x_{MDM}	1.00
x_{DSLM}	128.00
x_{BRAS}	10.00
x_{MSRVR}	176.00
x_{ESRVR}	44.44
x_{CNT}	11.11
x_{INSTR}	100.00

The OPEX of each IPTV component is assumed initially to be zero and can increase if time elapses and/or the number of subscribers increases.

From research adopted in Iran, the OPEX associated with infrastructure part of the network is assumed to be a decreasing function of *m* and an increasing function of both n and t.

In the following equations, parameters beginning with C represent CAPEX and those beginning with O represent OPEX.

The CAPEX and OPEX of IPTV components can be modeled as follows:

$$\begin{aligned} C_{STB}(n,t) &= \left(x_{STB} + (y_{STB} - x_{STB})e^{-z_{STB}n}\right)\cdot\left(2 - e^{-e_0 t}\right) \\ O_{STB}(n,t) &= x_{STB}\left(1 - e^{-e_1 n}\right)\left(1 - e^{-e_2 t}\right) \end{aligned} \tag{1}$$

$$\begin{aligned} C_{MDM}(n,t) &= \left(x_{MDM} + (y_{MDM} - x_{MDM})e^{-z_{MDM}n}\right)\cdot\left(2 - e^{-e_0 t}\right) \\ O_{MDM}(n,t) &= x_{MDM}\left(1 - e^{-e_1 n}\right)\left(1 - e^{-e_2 t}\right) \end{aligned} \tag{2}$$

The Eq. 1 and 2 describe that the CAPEX of the Set Top Box and ADSL modem are increasing functions of time t and decreasing functions of the No. of subscribers n (Aoki *et al*., 2006).

Furthermore, it is trivial that the OPEX of these devices must be increasing functions of both time t and number of subscribers n as in Eq. 1 and 2.

$$\begin{aligned} C_{DSLM}(t) &= x_{DSLM}\cdot\left(2 - e^{-e_0 t}\right) \\ O_{DSLM}(n,t) &= x_{DSLM}\left(1 - e^{-e_1 n}\right)\left(1 - e^{-e_2 t}\right) \end{aligned} \tag{3}$$

$$\begin{aligned} C_{BRAS}(t) &= x_{BRAS}\cdot\left(2 - e^{-e_0 t}\right) \\ O_{BRAS}(n,t) &= x_{BRAS}\left(1 - e^{-e_1 n}\right)\left(1 - e^{-e_2 t}\right) \end{aligned} \tag{4}$$

The Eq. 3 and 4 describe that the CAPEX of the DSLAM and BRAS are increasing functions of time t but do not depend on the number of subscribers n because the DSLAM or BRAS is bought only by the service providers and large companies not real persons, so their initial price (CAPEX) seems not to be dependent to the number of subscribers.

Furthermore, the OPEX of the DSLAM and BRAS must be increasing functions of both time t and the number of subscribers n as in Eq. 3 and 4.

As Eq. 5 describes, the CAPEX of the media server is an increasing function of time t but do not depend on the number of subscribers n because there exist only two (original+backup) media servers in the IPTV development plan.

The OPEX of media server is an increasing function of t and n.

$$\begin{aligned} C_{MSRVR}(t) &= x_{MSRVR} \cdot \left(2 - e^{-e_0 t}\right) \\ O_{MSRVR}(n,t) &= x_{MSRVR}\left(1 - e^{-e_2 t}\right)\left(1 - e^{-e_1 n}\right) \end{aligned} \quad (5)$$

In Eq. 6, the CAPEX of the edge server is an increasing function of time t but do not depend on the number of subscribers n because it is just for the service providers' use.

The OPEX of edge server is an increasing function of both t and n.

$$\begin{aligned} C_{ESRVR}(t) &= x_{ESRVR} \cdot \left(2 - e^{-e_0 t}\right) \\ O_{ESRVR}(n,t) &= x_{ESRVR}\left(1 - e^{-e_1 n}\right)\left(1 - e^{-e_2 t}\right) \end{aligned} \quad (6)$$

The CAPEX associated with the content is assumed to be fixed. Also, it is assumed that there is not any OPEX associated with the contents (Eq. 7).

$$C_{CNT} = x_{CNT} \quad (7)$$

It is assumed that the network infrastructure exists during the IPTV service development, so, there is not any CAPEX associated with this component.

As can be verified in Eq. 8, the OPEX of the network infrastructure is assumed to be increasing functions of t and n but decreasing function of the number of edge servers m because of the load balancing property of the edge server number increasing (Tanenbaum, 2002).

$$O_{INSTR} = \left(x_{INSTR} + y_{INSTR} e^{-z_{INSTR} m}\right) \cdot \left(p_{INSTR} - q_{INSTR} e^{-s_{INSTR} n}\right) \cdot \left(v_{INSTR} - w_{INSTR} e^{-u_{INSTR} t}\right) \quad (8)$$

Other parameters in Eq. 1-9 and obtained based on the research in Iran's market as follows:

$y_{STB} = 0.8x_{STB}$; $y_{MDM} = 0.8x_{MDM}$; $y_{INSTR} = 0.11x_{INSTR}$;
$z_{STB} = z_{MDM} = 3\times10^{-6}$; $z_{INSTR} = 0.002231$; $u_{INSTR} = 0.00886$;
$p_{INSTR} = q_{INSTR} = s_{INSTR} = 1$; $v_{INSTR} = 1.1$; $w_{INSTR} = 0.1$

The value of e_0 and e_1 for each device is considered as 10% of the initial cost in the Table 1.

Finally, TCO for an IPTV service can be calculated as follows:

$$\begin{aligned} TCO(n,m,t) = {} & n\left(C_{STB} + O_{STB}\right) + n\left(C_{MDM} + O_{MDM}\right) + \left\lceil \frac{n}{\theta} \right\rceil \cdot \\ & \left(C_{DSLM} + O_{DSLM} + C_{BRAS} + O_{BRAS}\right) + C_{CNT} + 2 \\ & \left(C_{MSRVR} + O_{MSRVR}\right) + m\left(C_{ESRVR} + O_{ESRVR}\right) + O_{INSTR} \end{aligned} \quad (9)$$

where, $\lceil x \rceil$ is the smallest integer number which is greater than or equal to x and θ is the No. of DSLAM ports. In this study, we have assumed that $\theta = 128$.

In the current study, we have tried to track the changes which are imposed on the optimal TCO as time evolves by regulating the number of edge servers m as a function of time. By research in the technical aspects of Iran's IPTV market, it is resulted that the number of edge servers can be regarded as a major parameter affecting the TCO of the IPTV solution.

Thus, the objective is to choose the optimal value of m so that the TCO is minimized.

It is obvious and legal that the number of edge servers m can not exceeds the number of subscribers n, so the constrained TCO minimization can be formulated as the following nonlinear programming problem (Bertsekas, 1999):

$$m^*(n,t) = \underset{0\le m\le n}{\arg\min}\ TCO(n,m,t) \quad (10)$$

For guaranteeing the uniqueness of the solution, the TCO function must be convex with respect to the m variable (Bertsekas, 1999).

From Eq. 9, we can write:

$$\begin{aligned} \frac{\partial^2 TCO(n,m,t)}{\partial m^2} = {} & y_{INSTR} \cdot z_{INSTR}^2 e^{-z_{INSTR} m} \cdot \\ & \left(p_{INSTR} - q_{INSTR} e^{-s_{INSTR} n}\right) \cdot \left(v_{INSTR} - w_{INSTR} e^{-u_{INSTR} t}\right) > 0 \end{aligned} \quad (11)$$

As it can be verified from Eq. 11, the TCO function is convex; hence the problem Eq. 10 has a unique and optimal solution.

An appropriate numerical approach is used to solve the problem for the optimal m and this method leads to the time-varying minimized TCO (Luenberger, 1984).

NUMERICAL RESULTS

The scenario shown in the Fig. 2 has been selected for simulation. This scenario is similar to one adopted for deployment of the IPTV service in Iran. In order to minimize the total cost (TCO) of the IPTV service, the minimization was performed with respect to m (number of edge servers).

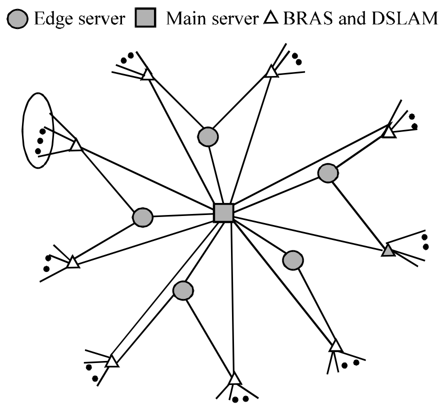

Fig. 2: Simulated IPTV service scenario

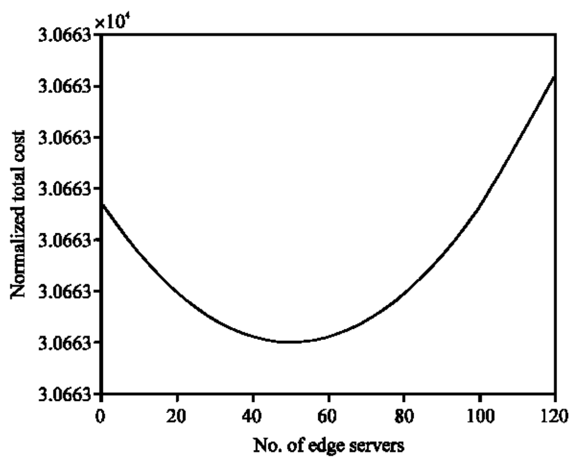

Fig. 3: TCO for n = 5,000 and t = 0

In other words, in Eq. 9, we have to determine the optimal value of m so that the total cost in this equation is minimized for a specific number of subscribers n and time t. Time means the number of years which have elapsed since IPTV service was first deployed (t = 0).

In the scenario, it is assumed that the end-users are distributed uniformly in a circular geographical region and for each $\lceil n/\theta \rceil$ user there exist a BRAS and a DSLAM. Each edge server can be connected to at least one DSLAM for streaming more demanding contents.

First, suppose that the number of subscribers is constant and is equal to 5000 (n = 5000). Then, we calculated the m that minimizes the total cost at the first year of service deployment or t = 0. The diagram of the total cost versus m for n = 5000 and t = 0 is shown in Fig. 3.

As it is clear from Fig. 3, total cost is minimum at m = 49. To see the effect of time on the optimal m (the m which makes total cost minimum), we again calculated the optimal m for n = 5000 subscribers and t = 10 years. As the Fig. 4 shows the optimal m is 53.

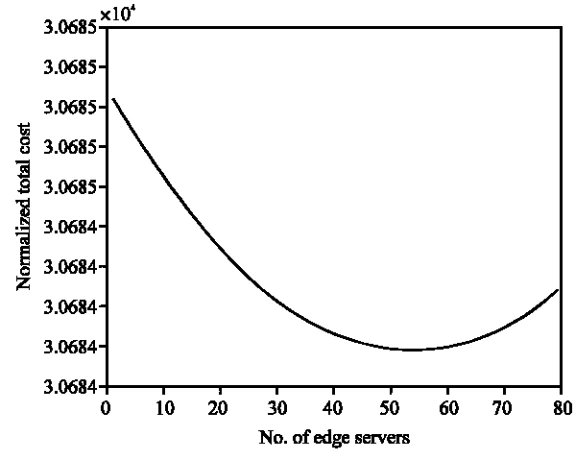

Fig. 4: TCO for n = 5,000 and t = 10

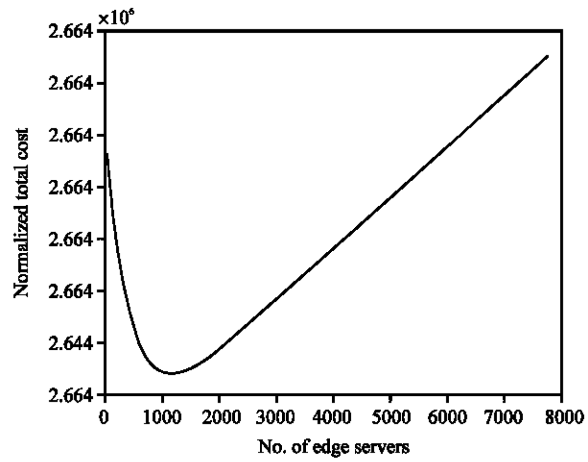

Fig. 5: TCO for n = 500,000 and t = 0

Figure 5 and 6 show the diagrams of total cost for the cases (n = 500000, t = 0) and (n = 500000, t = 10). Optimal m in these cases is 1159 and 1163, respectively.

Figure 3-6 show that the value of m which minimizes the total cost of IPTV changes as either the No. of subscribers or time changes.

To see the effect of time more clearly, the diagram of the total cost for n = 5000 during the temporal period of t = (0 1 2 ... 20) has been sketched (Fig. 7).

At last to see the changes of optimal m versus time and No. of subscribers, the optimal m has been calculated for n = (5000 10000 15000 ... 1000000) subscribers and t = (0 1 2 ... 20) years (Fig. 8).

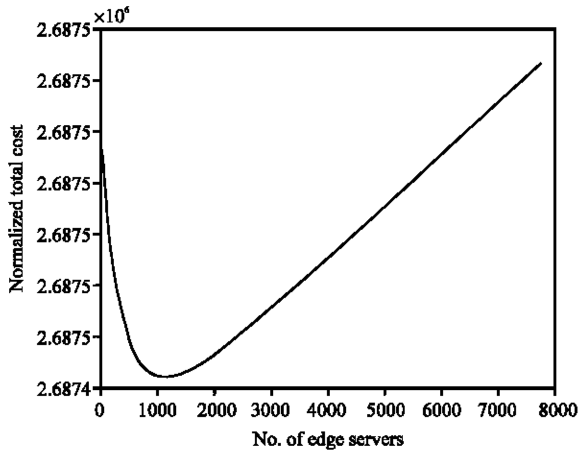

Fig. 6: TCO for n = 500,000 and t = 10

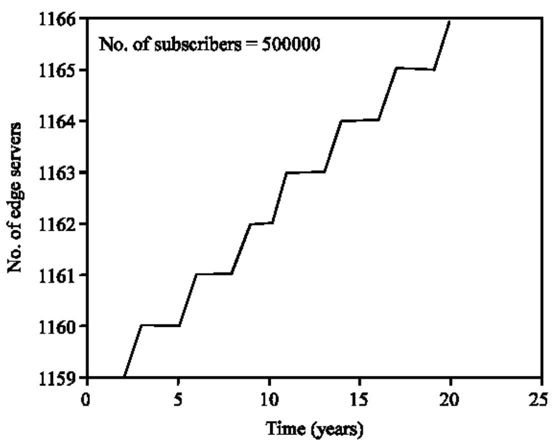

Fig. 7: Optimal No. of edge servers versus time

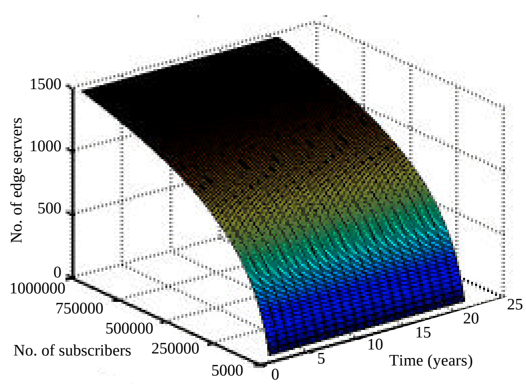

Fig. 8: Optimal No. of edge servers versus time and No. of subscribers

Figure 9 shows the variations occurring in the TCO of IPTV deployment with increasing time and No. of subscribers.

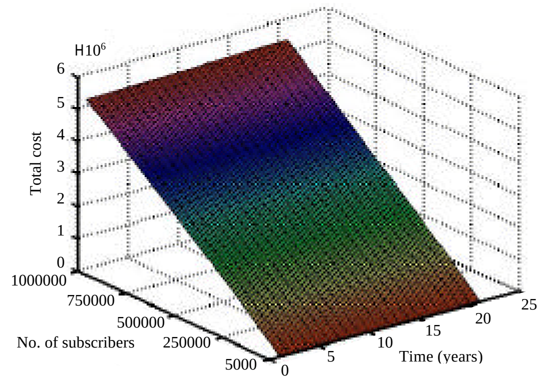

Fig. 9: TCO versus time and No. of subscribers

CONCLUSION

Though IPTV and VOD services are very attractive to the end users, they are highly expensive and this has caused them to be developed with a very slow pace. Minimizing the TCO (CAPEX+OPEX) of these services is a challenge to all IPTV and VOD service providers. In an IPTV scenario one of the major factors that determine the cost of the service is the No. of edge servers. An optimization method has been developed to minimize the TCO using selection of an optimal No. of edge servers in a typical IPTV scenario. This leads to the lowest cost of service deployment. The proposed optimization has proved to be quite efficient and dynamic in minimizing the TCO of IPTV as the number of subscribers' increases and time elapses.

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