A descriptive model for aligning the goals of the Internet stakeholders in LDCs

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Abstract

The Internet as a platform for services provision and delivery is adopted world over. To least developed countries it is further perceived as a medium for fostering development. A perception that is likely not to be easily achieved because the decisions that led to its existence in such countries never addressed the need of aligning the stakeholders’ goals which inherit the misalignments in present Internet architectural model. We present a model based on AHP theory that lays strategies through which informed decisions for aligning stakeholders’ goals can be made to use the Internet as medium for enhancing national development initiatives.

Keywords: ISCD model; Internet; development; LDCs; strategies; AHP; decisions

1. Introduction

From an industrial point of view; the computing, telecommunication and broadcasting sectors are converging to IP technology (hereinafter referred to as the Internet) as a unifying platform for services delivery. This move is believed to benefit all stakeholders (end users, network providers and policy-makers). For end users, it enables access to richer content via a single subscription anywhere anytime. Network providers have to build only one network, eliminating cost of building and managing multiple networks with different technologies. For policy-makers, concern is more on the positive livelihood transformations of society, which ultimately leads to an information society where everyone is able to control and manage one’s destiny.

Despite of converging services and its uptake in the developed world, we argue that, for an end user with limited financial resources the issue is not about unifying technology or convenience of accessing bundled
services in a single subscription. Rather, it is more about the value/utility one can attain from a service. On that basis, this research evaluates relative importance of various Internet Services in the Context of Development (ISCD) to a common user whose financial capabilities are limited and who operates in an environment of limited network infrastructures like those in LDCs where broadband is starting to take root. Thereafter strategic options are laid down through which stakeholders goals in view of ISCD can be aligned.

2. The problem of misalignment within the present Internet architectural model

We give a basic description to the fundamental problem of misalignment between the stakeholders and show how such misalignment is inherited from the present Internet architectural models.

2.1. Network provider’s perspectives of the Internet services provision

The goal of a network provider in the present Internet architecture is to earn the maximum possible profit on every bit that traverses his/her network. To achieve such a goal the provider ensures optimal utilization of one’s network resources and minimization of the operational costs. In this context network efficiency becomes a point of great concern to them. Herein efficiency is defined as the ratio of network throughput to the total available capacity. From a monetary viewpoint, each unit capacity of the network utilized is equivalent to a specific revenue/income. The more capacity utilized the higher is the provider’s income. Hence is the worth of the provider’s services to one’s self in achieving one’s goal of profit maximization.

2.2. The end users’ internet usage/connectivity perspectives

An end user signs a contract with the network provider that specifies one’s preferred services and acceptable quality of services (QoS). It is on this basis that determines the price of the link capacity/bandwidth the end user has to pay. The end user goal for paying the price for the link’s capacity is to maximize one’s utility. In this context, the utility expresses the extent to which one can achieve the maximum benefit expected from one’s preferred services that compensates for one’s connectivity costs.

2.3. Internet architectural setup (taking advantage of the open-architecture)

It is evident that the original goals of the Internet architecture were not for commercial gains. Even though it has evolved into the realms of the commercial gains, it still carries some original characteristics (openness, resource sharing, accommodating or federating with any technology, etc.). It is important to note that in the present data networks the link resource is shared among the several end users. As each link resource is finite, the end users are essentially competing for the scarce resource. However, the Internet models in use hide from the end users the conditions of competition between them. The models enable the network to communicate with the end user on an individual basis as each individual traverses a path of one’s choice. When the end users demand exceed the link’s resource then the questions of congestion and fair resource sharing arise. Accordingly, the network invokes its congestion control mechanism to notify the end users (i.e. the sources generating the traffic) about the state of the network and ensure fair distribution of the available resources. In this respect, the network sets the virtual price$^1$ (which, it charges the end user per supplied unit of bandwidth)

$^1$Virtual price: This is the price the link algorithm computes as a function of time that converges to the Lagrange multiplier corresponding to the link’s resource constraint. The price is transmitted to the sources in conjunction with the source algorithm, and then sources are able to regulate the transmission rate.
and each end user reacts to the price by revealing the preferred amount of bandwidth. The network then adapts the virtual price and the process continues.

2.3.1. Original misalignment in the Internet architecture

It is desirable that the individual based (iterative) virtual prices and link resource adaptations reviewed in the above paragraph their convergence guarantee to the utility-maximizing and profit-maximizing prices. In such a case the resource allocation reached would reflect both the network’s and the end users’ objectives. Then one could view these objectives as “aligned” since the network’s interest to set prices for the allocated capacities to the end-user which are achieved at the equilibrium point would also maximizes the end users’ aggregate utilities “net benefit” (social welfare). However this is not always the case. The achieved capacity levels end in providing the optimal flows which are translated as optimal resource utilization. This directly favours the network provider. Not necessarily that at optimal flow all competing flows get the required capacity shares that optimizes the end user’s utility (i.e. not all flows attain the recommended capacity levels to deliver services with expected QoS by end users). Generally some flows are degraded because of their in-built elastic resource sharing mechanism.

It is easy to note in this qualitative analysis of the problem of misalignment given, the network act as price-setter while end user is the price-taker as they adjust their desired bandwidth according to the prevailing network situation. This is very much common in LDCs where the infrastructures are still weak.

Work based on optimal flow control framework mainly pioneered by Kelly have been studied extensively in view of aligning or converging the end user and network objectives and integration of the fairness concept in bandwidth allocation among competing users. The analytical settings of the alignment convergence to an equilibrium point is well studied in and associated stability issues and network performance addressed in and references there in. All these studies strive to find an “optimal” resource allocation so that the sum of all the end user utilities is maximized in pursuance of maximum of social welfare in a network especially for elastic flows/traffic, i.e. the TCP traffic. Quite a few further works also deal with flow-level stability issues of utility-based allocations in non-convex context.

2.3.2. New breed of misalignment in the provision of Internet services

Despite of the great advances by using the optimal flow control theory and its application in setting the alignments, serious limitations are springing up that will continue ring circling the Internet from the low-income earners mainly from poor nations. In the event of well-established infrastructures, network provisioning is the order of the day in avoiding congestion hiccups. In such scenarios, most of the providers have now shifted from the rate to volume costing of the internet usage as a way of maintaining their egos for profit maximization. Even though there are some good arguments for volume costing, we note that it is a way to block an ordinarily customer from exploring the full features of the Internet and also brings another dimension of misalignment between the Internet/network providers and end users in the placement of the value each achieves from the provision and consumption/usage of the Internet.

To the Internet/network provider the value is proportional to the number of bits end users push through one’s network. That is the Internet/network provider’s value is created in the network. While the end users the number of bits one pushes through the network is not necessary proportional to the value one gets, although the volume costing assumes a direct proportion and charges the end user for having engaged the infrastructure accordingly. We acknowledge that the network infrastructure (routers, wires, radios, etc.) are all vital, but they are just means to the value a user gets from the Internet. Therefore for end users the value from the Internet is made outside the network. For example, consider a case of e-learning. A fulltime employed end user based in LDC needs to upgrade one’s skills to match the international standards. The end user cannot leave one’s job to travel abroad and attend international professional school to pursue higher/advanced professional courses. Even s/he has no money for one’s up-keep and tuition requirements, leaving alone the barriers of getting visas to a
developed country while one is coming from LDCs. Therefore end user uses the Internet access to register and pursue the professional course at a school based in a developed country. On successful completion end user’s skills are improved and her/his value of human capital is rated at higher. Hence is the expected salary/income from one’s employer/market. That is the increase of human capital value (improved competencies, knowledge, social, ability to perform labor, etc.) is made outside the network but glossily enabled by the network/Internet.

In the real-world scenarios the cost of an item/service is always proportional the value contained within the item/service. Consequently the purchaser directly exploits the value from the item/service. It is evident from the above given example, the value an end user gets from the Internet usage is not directly exploited from (neither proportional to) the volume of the bits s/he generates in the network. Therefore the costing of the Internet usage based on volume of the bits an end user generates in the network is a wrong assumption to be equated to value one achieves. Hence agitators of volume costing are introducing a new breed of misaligning the provision of Internet services (i.e. misaligning the Internet cost, volume of the bytes generated, and the value an end user gains from the Internet usage).

3. Approach to the alignment of stakeholders’ goals

To develop strategies for solving the misalignment problem mention above, a two stage approach is proposed.

Stage 1 - classify the Internet services by their traffic characteristics to objectively compute their corresponding utility values in context of development. This approach is based on the principles that each service delivered over the Internet has corresponding applications end users use to achieve their objectives. In turn, each application generates a kind of traffic over the Internet in order to deliver the required service. However the number of applications (therein services they deliver) continues to grow daily, making it complex to make an objective comparison among ever changing numbers in the effort to establish relative values/utilities the end user achieves from using an application/service in context of enabling development. Noting the present Internet traffic is classified in a few classes regardless of the numerous applications and their respective services that generate the traffic, it makes computational feasible to characterize the delivered services by their traffic class characteristics.

Stage 2 – establish Internet traffic classes’ relative importance in view of ISCD. This approach uses the analytic hierarchy process (AHP) theory to model the problem of establishing utility vectors of Internet traffic classes through which the strategic options for aligning stakeholders’ objectives are developed.

4. Classification of Internet Services by their traffic characteristics

The Internet traffic classes are distinguished by their respective (a) traffic characteristics/behaviour in respect of network resource requirements, (b) network resources metrics (i.e. QoS recommend levels by standardization bodies), and (c) utility function. We present their classification in figure 1. The figure gives more fine-grained information that matches the five Internet traffic behavioral classes to seven groups of Internet services. Also it purposefully shows the service convergence paradigm onto all-IP technology.

The essence of matching/mapping traffic classes and end user services to bandwidth utility functions is to devise means of managing the complexity of a wide range of core network functions to meet the diversity of user needs. That is, at network level the utility functions are evoked to ensure fair distribution of network resources to the users’ applications flows and maintain the required end user operating quality through proper management of the core network functions (equipment configuration, traffic engineering, services level agreements, billing, and customer support). Therefore human requirements for services to be delivered by a particular traffic class are fulfilled by meeting the specified quality metrics in its corresponding utility function.
We noted above that earlier studies have strived to use the optimal flow control methods to ensure optimal network resources utilization and fair allocation to all competing end user flows. But not all fair allocations at the optimal levels meet the minimum required bandwidth for the respective traffic flows to deliver satisfactory services with the minimum required utility levels to the end users. Our innovative method in the next stage enable to establish utility levels for traffic classes that assure the delivery of a service that meets end-user satisfaction in the context of ISCD. End user satisfaction with the received services deliveries aligns with one’s goals of maximizing one’s utilities.

Hence this innovation leads to aligning the end users goals of maximising one’s utilities with the provider goals which are achieved from the optimal control methods as earlier discussed.
5. The ISCD model - establishing Internet traffic classes’ relative importance

The hierarchy shown in figure 2 depicts the process of structuring the problem of establishing the relative importance among the Internet traffic classes (therein Internet services) in the context of development using the AHP method of modelling. The top of the hierarchy defines the ultimate goal. Below the goal are the aspects/clusters, criteria and the alternatives form the lowest level of the hierarchy.

![Figure 2: AHP based model for ISCD](image)

The goal definition for modelling the problem is prioritization of Internet traffic classes (therein respective delivered services to end users). The alternatives elements of the model are traffic classes where $T_1 =$ Hard real-time traffic class, $T_2 =$ Real-time non-interactive traffic class, $T_3 =$ Real-time interactive traffic class, $T_4 =$ elastic interactive traffic class and $T_5$ is Elastic non-interactive (commonly called Best Effort) traffic class.

5.1. Aspects/Clusters and Criteria for the Model

There are three aspects/clusters developed in this model. Marked as AS1: Services relevance in context of development, AS2: Services Delivery Mechanism Convergence to IP Infrastructure and AS3: Services Commensurability to Traffic Classes’ Requirements. Though generic, their development is based on well-established core factors in the scholarly literature and ICT4D practitioners’ experiences. The criterion for evaluating each aspect/cluster is therein described.
5.1.1. AS1: Services relevance in context of development

The aspect weighs the traffic class importance based on the relevance of services it delivers to end users (communities) in LDCs. Four criteria used to measure the preference level of the traffic class services’ relevance in context of the development are defined as;

5.1.1.1. AS1C1 – User empowerment

Relevance is viewed in context of increasing the capacity of individuals or groups to make choice and to transform those choices into desired actions and outcomes that contributes to the wellbeing of an individual, communities and the society. Empowerment achieved from the Internet services in this respect is also central in inducing or fostering power in people to perform normative actions that are accepted in a given cultural setting of the communities.

5.1.1.2. AS1C2 - Population in-need

This criterion weighs the delivered services based on the level/number of population in-need of such a service/s as delivered by a particular traffic class. It assumes that the higher the number of such low income people yearns for a service then the higher the relevance of such a service is to their lives or in their communities.

5.1.1.3. AS1C3 - Must have service/s

From the literature and the existing ICT/Internet myths, there are services deemed as must have by everybody. These are Internet services deemed to have sustained its growth from more than two decades. It is on the basis of such services that some nations, International organizations, civil societies are declaring or agitating for the right to Internet access. Their relevance in fostering development in LDCs is non debatable, hence the traffic class/es that deliver them should be given high priorities in the networks.

5.1.1.4. AS1C4 - Impact to communities/group of user

This criterion weighs (what is or what would be) the positive impact to the end users/communities in accessing the Internet traffic classes’ associated services. Services that can cause people’s mind-setting, behavior change, manner-setting, high awareness, in a positive direction of improving their wellbeing. In this context the wellbeing is considered in multidimensional aspects (spiritual, emotional, healthy, and financial).

While evaluating the criterion dominance/preference against the other, the mind frame for the evaluator should be focused on given traffic class services’ contribution to basic dimension of development (economic productivity, education, democracy and quality of life in respect of individuals’ health and happiness within the society).

5.1.2. AS2: Services Delivery Mechanism Convergence to IP Infrastructure

The existence of the IP-Infrastructure in a locality/state is a clear indication of the availability of the Internet services. Conversely we cannot talk of the importance of the Internet services in context of development while there is no core underlying IP infrastructure. It is well known that countries in LDCs lack sufficient infrastructure to deliver the-state-of-art services which may accelerate or enhance development initiatives. In case where some level of services exists, such services are delivered over the old technology with limited capacity to accommodate big numbers of users. Hence hiking the cost of services and consequently eliminating the majority of the interested people in-need of services. In the event of realizing the importance of a service which is normally coupled with demand from end users, providers are in process of migrating from their legacy systems to IP based systems which are envisaged to have low operational cost, continuous support from
equipment vendors, and fully compatible with the present market demands services to the next generation networks and services.

This aspect weighs the technological trends of convergence to all-IP in delivering services of the (or similar to the ones of) traffic class in context of development. The acceptance by services providers or/and end users in LDCs to migrate to all-IP platforms to deliver/receive such services has a bearing in demonstrating the importance of such traffic class services in context of development. Three evaluation criteria identified are;

5.1.2.1. AS2C1 - Migration to all-IP infrastructure

It refers to trends in technology migration to all-IP infrastructure in view of providing a scalable infrastructure that can meet the end users’ social dynamic demands.

5.1.2.2. AS2C2 - Technology availability

Refers to whether the state of technology required for the delivery and receipt of traffic class services exists in LDCs. That is availability is weighed in view of the stakeholders (both the network provider and end users) possession of the infrastructure with the state of technology that can deliver or receive the traffic classes’ services. That is the decision maker (DM) weighs the importance of these services in context of fostering development based on the possibility of technology availability (i.e. provider providing required connectivity and capacity/bandwidth over IP infrastructure and end users possessing the required terminal equipment (TE) confirming to the needed technology). The DM makes one’s judgments based on her/his knowledge and expertise on what technology is available in LDCs now which can be used as a springboard for delivering services to enhance development.

5.1.2.3. AS2C3 - Coverage range

Refers to the how well an area (region) is covered in receiving a transmission signal that can deliver services based on the IP infrastructure. The coverage capability is always expressed quantitatively as a statistic value. Such a statistic depicts the coverage percentage of a nation that can receive the transmission signal or/and a household services penetration. In respect to LDCS, wireless access technologies are the most prominent networks. Their coverage indictors are normally provided by the network providers in a form of percentage of population able to access the services or percentage of the geographic area where they have presence. For wired networks the coverage statistics are normally given in form numbers of points of presence in terms of either absolute customer connections. Other measurable parameters that could be represented statistically and are relevant with this study are network traffic, available bandwidth, and bandwidth cost. Consequently a traffic class (conversely traffic class delivered services) whose state of technology for delivering its services has a high coverage static, is assumed to be of high importance to the end users in this study. The basis of the argument is that network providers are more driven by users’ demands in deploying their infrastructure. Hence the usefulness or importance of a service to low income earners is reflected by the demand.

5.1.3. AS3: Services Commensurability to Traffic Classes’ Requirements

In consideration of the state of infrastructure in LDCs this aspect evaluates the traffic class importance in view of its network centric and end user centric requirements. In this study network centric refers to attributes thought to be determinate in the delivery of services over IP infrastructure. The user centric focuses only the affordability of possessing a terminal equipment and continuous subscription for the Internet connectivity. Consequently we identify three evaluation criteria as;

5.1.3.1. AS3C1 - Services’ network demands

This refers to the network centric requirements for a traffic class in delivering reliable services to end user. The Obvious common observable network resource demands in LDCs are bandwidth and power (transmission
However, depending on the connectivity technology in place and the terrain of the area, further network centric attributes (packet loss, jitter, throughput, delays, and payload size) may contribute to delivery of services with retarded QoS. Hence in weak infrastructure it is necessary for a DM to put in consideration such additional network centric attributes when weighing the traffic classes network resource demands.

5.1.3.2. AS3C2 - Terminal equipment affordability

This criterion refers to the affordability of end user terminal equipment to access services delivered by a traffic class. Different traffic classes deliver services that demand the possession of terminal equipment with different levels of capabilities (processing speed/power, memory storage, display resolutions, power consumption levels, etc.). Hence services in-need influence the type of terminal equipment an end user should possess. The horizontal weighing of this element vis-à-vis others on the same hierarchy or the vertical weighing of all the underneath alternatives (traffic classes) have to put these considerations.

5.1.3.3. AS3C3 - Affordability of recurring costs of access

This criterion refer to affordability of recurring costs for Internet connectivity (whether fixed rate or volume costing) and online content/services access where applicable. Noting that different traffic classes (therein services) need different levels of bandwidth hence different levels of continuous payment, it is necessary to identify those services (hence their corresponding traffic classes) whose their required bandwidth and access are within affordable range for the majority of end users in LDCs.

5.2. The Atomic Elements (Alternatives) of the Model

The alternatives are the atomic elements at the lowest level of the AHP model. In this model they represent the Internet traffic classes ($T_i, \forall i = 1, ..., 5$). They are the elements to be assessed/judged. The preference among the set of alternatives is determined by employing pairwise comparison of the hierarchy elements at all levels following the rule that; at a given hierarchy level elements are compared with respect to elements in a higher level by using the fundamental importance scale $16$.

The synthesis is performed by multiplying the criteria-specific priority vector of the alternative with corresponding criterion weight and summing up the results to obtain the final composite of the alternatives’ priorities with respect to the goal. The highest value of the priority vector indicates the best-ranked alternative.

6. Mathematical foundations of the model

The Mathematical technique of the pairwise comprises (PC) is the foundation of the model $17,18$. The PC technique is used in measuring the intensity of preference between two elements using the AHP fundamental scale of absolute numbers to establish the ratio while putting in consideration the cardinal intensity of preference between elements.

The model adopts the eigenvector approach $19,20$ in the process of computing the relative preference vector for each criterion at the respective hierarchy and then finally a normalized geometric mean method $21$ is used in the aggregation process that leads to the global preference vector.

7. Conclusion

The problem of misalignment among the Internet stakeholders’ goals in LDCs has been presented. The origins of the problem are observed as (a) the Internet architecture still possesses some original design that were not met for commercial goals even-though are now redirecting the Internet developments, and (b) placement of the value (for every stakeholder gets from the Internet services) in the network.
A strategic approach of addressing the problem is proposed to stem from the Internet traffic classes that deliver the required services to the stakeholders. Traffic classes are fewer in number while they embrace all the numerous and ever increasing in number of the Internet applications (therein services they deliver to end users). Hence the computational process of establishing the Internet services utility for end users becomes feasible while handling only the traffic classes since they have a direct mapping to Internet services/applications.

AHP based model for structuring the problem is presented whose implementation lead in establishing utilities levels through that Internet providers would adhere to in providing services to end users that also maximizes their utilities. This method would lead to the alignment of stakeholders’ objectives for ISCD.

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