TOPICS IN OPTICAL COMMUNICATIONS

On the State and Guiding Principles of Broadband in India

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ABSTRACT

India, home to 1.2 billion people with a GDP growth of 9 percent, has been experiencing flat to modest growth of broadband services in the past decade despite the fact that the country continues to add 8–10 million cellular connections per month. In this article, we examine the reasons that affect the high cost of broadband in India and the steps required to reduce the cost. We also argue that the usage-based pricing model, which is used widely for billing retail customers, is hampering the growth of local content and services. In contrast, a flat-rate pricing model would spur demand for broadband services and enable content providers to target the local and emerging market. We study the Indian telecommunication scenario from a pricing and technology perspective to understand what the driving forces are for business to prosper. We then discuss the Indian landscape from a metro/access/core networks perspective. The technology choices and the methods of deployment are considered followed by an analysis of the service-centric model adopted by providers.

INTRODUCTION

Internet usage in India has grown at a modest rate in the past several years in contrast to the 8–10 million cellular lines that are added each month. Although the number of Internet subscribers in India has been growing at about 25 percent from 2004 to 2007 [1] (Fig. 1), the actual consumption of bandwidth has been a poor 87 Gb/s [2]. This subscriber growth has been significantly less than what was expected and is about 6 percent of that of the People's Republic of China and 4 percent of the United States [3].

Particularly worrisome is the sluggish growth in the broadband sector of both retail customers and small enterprises. Historically, across the globe these segments have implied the emergence of access users that lead to voluminous growth and Internet proliferation, thereby achieving an e-lifestyle. Penetration of broadband in India remains low, and the targets set in the national broadband policy remain unachieved (Table 1), as also shown in Fig. 1.

The current demand for Internet bandwidth within the country is driven primarily by software exporters, information technology enterprise solutions (ITES), banking, software service providers, and the finance sector. Most of these industry segments are classified under the umbrella of business process outsourcing (BPO), thereby making broadband a key to the back-offices in India. Home users constitute only a small share (typically in the single digits in terms of usage) of this demand. Applications of broadband in the Western world such as healthcare, *telemedicine*, and *video-on-demand* are either missing or exist in negligible numbers. Even when present, such home applications are limited by poor service-level agreements (SLAs) in the last-mile (residential users). The number of Internet subscribers in the country is small, and those with broadband connections are even smaller. Hence, the present market for local content and customized Internet services is negligible, limiting the gateway and access rights of international bandwidth into the country to submarine landing points.

Although the Indian economy is growing rapidly at 7–9 percent per annum, resulting in a huge untapped market for Internet service providers (ISPs), the retail segment, despite its high purchasing power (PP), has not blossomed to entail creative, competitive, and cumulative business. There is stagnation in the growth of Internet services in India, which leads to saturation of broadband needs. Most retail customers have Internet connections that are narrow (< 256 kb/s). This implies that prevailing applications are restricted to e-mail and Web browsing with limited multimedia content. The pricing structure of broadband in India is arguably one of the highest in the world (Table 2), making it an elite or luxury item. Surveys and blog [5] entries have suggested that small enterprises and residential users want better (more) bandwidth at an affordable price. Why does a scenario of a scarcity of broadband prevail?

BANDWIDTH STARVATION: AN ANALYSIS

As seen in Table 2, the cost of bandwidth in India is high. Both retail and corporate customers are deterred by the high price of bandwidth [6], which is primarily due to the near

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monopolistic policies during the past decade exhibited at the landing points of submarine links. Indian enterprises use high orders of statistical multiplexing that cater to a large number of internal users with a minimum dedicated bandwidth.

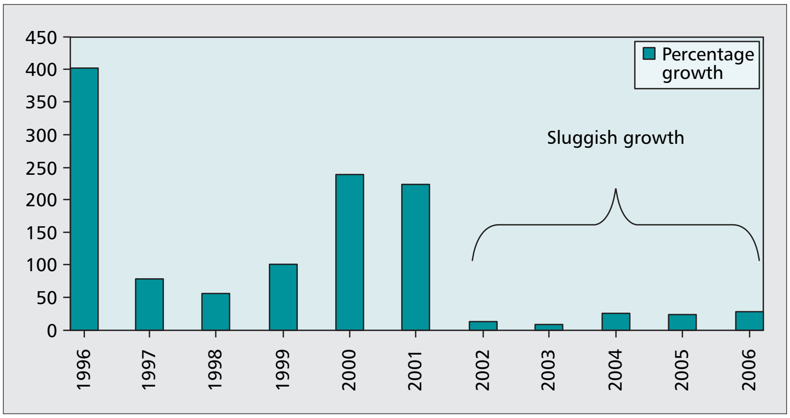
The usage-based pricing model that is presently deployed for retail customers dissuades them from using Internet multimedia services extensively like voice over IP (VoIP), video sharing, streaming media, and social networking portals. Retail users use less bandwidth-consuming services such as browsing, e-mail, and chat.

Because the number of users with high-speed connections is low, next-generation Internet applications, content providers, and data centers that require more bandwidth have been wary of putting up shop in India. Though this trend is slowly changing now, it will take a long time for the gap between the content available in the Western world and India to be bridged. This in turn results in consumers not demanding high-speed Internet connections because they do not use services that require such connectivity. This feedback loop creates the fallacy of local intra-networking, which explains the rise, penetration, and success of cellular services for both voice and short message service (SMS) texting applications. The short-term benefit generated by cellular technology is heralded as a telecom revolution, which neglects the problems caused by denial to voluminous, dynamic, and much-needed information.

Poor quality-of-service (QoS) also has been blamed for sluggish broadband Internet services in the country. It was not until 2007 that the Telecom Regulatory Authority of India (TRAI) formulated guidelines for ISPs regarding QoS. Users have little incentive to switch to a broadband connection if the service provided by the ISP falls short of the standards desired for multimedia content.

In most places, although the network is new and there is available installed capacity, the actual in-use capacity is only a fraction of the installed capacity due to a limited capital expenditure (CAPEX) budget and due to the lack of business foresight. It is worth noting that unlike the developed world, where providers have in-house research laboratories, no provider in India focuses on telecommunication research.

To make matters worse, a unique provider-vendor business model has emerged, one that brings in the vendor to lease equipment to a provider, thereby sharing profits (between the vendor and the provider). This implies that the network is at the mercy of the vendor in terms of technology roadmaps, as long as the vendor can provide for the basic business needs of the provider. This also implies that the provider is more focused on its marketing and sales strategies than on the actual ownership of the network. In fact, most of the overhead is in sales and marketing, neither of which is directly responsible for good network planning.



■ **Figure 1.** *Percentage growth of Internet subscribers over the years [1].*

In the sections that follow, we examine each of the reasons listed above that are key to the sluggish growth of broadband. We first analyze why bandwidth in India is expensive, even more so than in countries with a lower gross domestic product (GDP) and lower PP. Subsequently, we discuss the advantages of using the flat-rate pricing model over the usage-based pricing model.

India's Networking Infrastructure

Submarine Cable Systems

International connectivity to India (seventh-largest country in area with 6000+ kms of sea border) is primarily provided through submarine optical-fiber cable systems. International submarine cables terminate at a *cable-landing station*. These cable-landing stations are in turn connected to backhaul facilities that link them to a service provider's existing national communication infrastructure/backbone. It must be noted here that a cable-landing station is an important *choke point* for an incumbent international operator to thwart competition. According to [2], India had nine cable systems and six cable-landing stations with a total design capacity of 18.6 Tb/s.

The cable owners can use tactics like *differential pricing* between their associates and competitors; delaying or denying capacities required by competitors and obstructing access to facilities and co-location at their cable-landing stations.

Year ending	Internet subscribers (in millions)		Broadband subscribers (in millions)	
	Target	Achieved	Target	Achieved
2005	6	5.55	3	0.18
2007	18	9.27 until March 2007	9	2.34 until March 2007

■ **Table 1.** *Targets set in the national broadband policy and what was actually achieved [4].*

Until recently, most of the landing points in India were controlled by a single operator, and even now, are controlled by a handful of operators with issues such as conflicts of interest with other local operators.

Country	Normalized price per Mb/s per month
South Korea	1
Sweden	1.91
Germany	15.68
United Kingdom	33.26
Poland	39.21
Luxembourg	55.79
China	68.18
Thailand	89.29
Sri Lanka	120.29
Slovakia	151.41
India*	260.62
Myanmar*	769.85

Table 2. *The table shows the normalized price of broadband connectivity as on July 2007 in different countries of the world. Countries marked with * have monthly download limits (e.g., 2 GB). Source is [5].*

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Hence, it is not surprising that only a fraction (3.5 percent as reported in [2]) of the 18.6 Tb/s bandwidth actually is provisioned and made available to the country. Naturally, a large portion of this bandwidth is used for enterprise and institutional customers. Despite an exhaustive search, it was difficult to compute the exact percentage of bandwidth made available to residential users. Of the 18.6 Tb/s installed capacity as of 2006, only 655 Gb/s has been provisioned. Of this 655-Gb/s available bandwidth, we estimate about 500+ Gb/s is made available to enterprises and institutional customers, thereby resulting in 155+ Gb/s-capacity to a nation of 1.2 billion people. Hypothetically, at an average user-utilization factor of 25 (1 in every 25 users is online at a given time), if we were to distribute this approximate < 200 Gb/s of bandwidth in the population above the age of 18 (which is about 800 million), each person would get 250 bits per second of net connectivity and 6.25 kb/s of shared connectivity (at 1 out of 25 users being active). Given that about 500 million of those individuals have no access to computing resources (falling below or just above the so-called poverty line of earning around $2 USD per day), would imply a net 667 bits per second of bandwidth — less than 1 kb/s, thus allowing 25 kb/s or so of shared connectivity to the 300 million plausible users. It must also be noted that at the time of this writing, developed countries particularly in the Far East and Western Europe have rolled out 50 Mb/s of net bandwidth per home/user at price points lower than those available for the 100~256 kb/s shared capacity present in India today.

Nationwide, Metro, and Access Networks

Domestic traffic within the country is transported on nationwide networks of various telecommunication operators. For example, a state-owned operator has a national Internet backbone (NIB) that connects more than 71 cities through a multi-protocol label-switched (MPLS) core over a wavelength-division multiplexing (WDM)-optical backbone. Optical fiber networks in India are being rapidly deployed. Table 3 lists the major players in the domestic optical-fiber network arena and the length of optical fiber that they have deployed showing the tremendous opportunities for growth. These optical fiber networks offer services like MPLS, Internet Protocol-virtual private network (IP-VPN), synchronous digital hierarchy (SDH) circuits, and metro Ethernet services. It can be seen that sufficient domestic communication infrastructure exists but is not utilized.

The last mile (connecting end users to service providers), except in metropolitan areas is sparse. In metropolitan areas, copper cabling is available that can support lower variants of digital subscriber line (DSL) such as asymmetric DSL2 (ADSL2). As mentioned in [7] more than 95 percent of the country's urban copper network is owned by incumbents and was deployed for telephony purposes. Multi-tenant unit (MTU)-type homes have implied long distances — of the order of 1000+ feet from the nearest point-of-presence (PoP), thereby limiting the use of advance variants of DSL, such as very high bit-rate DSL (VDSL), which can give 10 Mb/s or so of connectivity. DSL remains the most widely used technology to deliver broadband services. For those tier 1 and tier 2 cities without copper infrastructure, initial deployments of worldwide interoperability for microwave access (WiMAX) have begun. It is debatable as to how deep WiMAX can penetrate into the residential broadband market due to the following reasons:

- High cost of basic bandwidth
- Regulation issues in the 2.4- and 5.2-GHz spectrum
- High cost of customer premise equipment (CPE) of the order of $200 USD per home

In select tier 1 cities, the incumbent provider has begun some basic deployment of fiber to the home (FTTH) and fiber-to-the-curb (FTTC). Although this is a good sign, at par with deployment in the developed world, the deployments are far too little to make a business impact. The key again is the absence of a comprehensive return on investment (ROI) model, due to the current broadband pricing strategy as a result of bandwidth choking.

The Internet Exchange

Another important component of Internet connectivity is the National Internet Exchange of India (NIXI). Four NIXI nodes were originally

Figure 2. *Landing points of submarine cables in India. Also shown are important Indian cities and some of the ISPs.*

Peering is an arrangement between two service providers to exchange traffic (typically at no cost to each other). In this way, the ISPs avoid paying a transit fee to a third carrier (generally a higher-tier ISP) who would have otherwise provided such connectivity.

set up at North India (NOIDA), Mumbai, Chennai, and Kolkata so that ISPs could peer between themselves and route domestic traffic within the country. Peering is an arrangement between two service providers to exchange traffic (typically at no cost to each other). In this way, the ISPs avoid paying a transit fee to a third carrier (generally a higher-tier ISP) who would have otherwise provided such connectivity. These NIXI nodes have been used insufficiently for peering purposes. This was an effort that was genuine in conceptualization but failed in implementation.

With this background on network structure in the country, we now discuss the broadband pricing structure that leads to sluggish broadband penetration in India.

Bandwidth Woes

The high cost of bandwidth is a major reason for the slow growth of Internet use in India. The problem is three-fold:

- Expensive international connectivity through submarine cables
- Poor network operations by ISPs
- An underdeveloped last mile infrastructure

In the year 2000, a study by the National Association of Software and Service Companies (NASSCOM) [8] estimated that India required 5 Gb/s of international bandwidth but at that time had an installed base of only 325 Mb/s. In contrast in 2001, a large U.S. university alone had more than 500 Mb/s of connectivity. Until 2003–4 the international bandwidth entering the country remained scarce. This was the main reason why the price of bandwidth in India was high. There was only one incumbent selling bandwidth. However, with the opening of the international bandwidth sector to private players in 2002, the situation today has improved [6], though it lags behind the international market by about two orders of magnitude. By the end of 2006, the cost of international bandwidth had fallen by more than 50 percent of what it was in 2000 but was still about 500 percent higher compared to other developing countries and one order of magnitude higher than that of the developed world [5]. The TRAI has made several attempts to fix international pricing, but has failed to enforce a quality of experience (QoE) to end users, as well as enforce a penalty to providers that violate SLAs. No study is available on the

The network is designed hierarchically for the ISP alone; no gateway traffic with other providers is assumed at the beginning and as the inter-provider traffic (peering) increases, the pricing for the same rises exponentially.

Network operator	Length of OFC deployed (km)
Incumbent I	550,000
Incumbent II	40,000
Private ISP I	80,000
Private ISP II	70,000
Utility company I	30,000
Utility company II	19,000

Table 3. *OFC networks in India.*

total penalty that has been levied on providers for not meeting broadband SLAs. This monopolistic trend and the ability to avoid penalty is because competition between submarine cable owners has not matured. Some of them continue to engage in monopolistic practices such as the refusal to permit interconnection at their cable-landing stations and the delay or denying of provisioning of bandwidth for competitors. Clearly, the immediate need is for an act that would limit companies engaged in submarine intercontinental networks to also deal in intra-country networks resulting in deregulation. International cable operators also have failed to activate additional capacity in their cable systems. This has resulted in an artificial shortage of bandwidth into and out of India that has inflated prices. Monopolistic practices by backbone providers must be regulated by unbundling the backbone. Anyone should be able to buy dark-fiber coming into India and light it up. A possible suggestion would be to allow 25 percent of every submarine fiber link (10 wavelength channels) to be used by third parties, sold in an open auction.

ISPs act as bandwidth resellers rather than network operators [7]. No effort is made to peer with other networks, reach out to content owners, or optimize network operations. The network is designed hierarchically for the ISP alone; no gateway traffic with other providers is assumed at the beginning and as the inter-provider traffic (peering) increases, the pricing for the same rises exponentially. In a majority of cases, the lack of peering results in domestic Internet traffic being routed over international cables only to come back into the country. This wastes international bandwidth and incurs delays. In fact, to a certain extent, network operation centers (NOCs) themselves are not aware of this, resulting in erosion of net profits for the ISPs. It is recommended that ISPs interact with content providers and welcome them into their networks. To do so, content providers must be given a lower pricing model. However, NIXI's infrastructure remains underutilized [9] because a limited number of ISPs have joined it, and some of them are not declaring all their routes. So a significant amount of domestic traffic still is routed internationally, with ISPs paying international rates for domestic traffic. Hence, Indian ISPs are unable to convince owners of popular content and data centers to move their services to India. The cost of operating a data center in India is two orders of magnitude more than the same cost in North America. Data centers are critical to host content. This has also meant that it is difficult to create, disseminate, and popularize information.

ISPs must demonstrate that they have requisite network operations so that national and international content providers locate themselves in India. For ISPs this will reduce the costs associated with buying international bandwidth and increase the number of subscribers.

Merely creating bandwidth will not suffice. There must be efficient means to deliver it to the user. The last mile in India still remains a bottleneck [10]. Creating last-mile infrastructure involves huge costs with tangible ROI models that are brought about through good governance, price-points, fair competition, and a strong customer base.

In urban centers, the existing copper network must be utilized to offer advance variants of DSL. India accounts for seven cities in the list of the top 20 population centers in the world. Meeting such large requirements implies heavy CAPEX. The CAPEX must be justified with a short return on investment cycles. With bandwidth being the single largest cost in terms of operating expenditures, no single ISP or even multiple ISPs could roll out efficient last-mile networks. Thus, ISPs are unable to increase their reach and scale operations. The existing copper infrastructure in select cities was built for voice, and is now a good source for tier-2 broadband communications (e-mail, Web browsing). However, as energy sources plummet and the need for telepresence, telecommuting, and video-on-demand increases, even the available copper infrastructure could not provide broadband connectivity. A roll out of WiMAX services would temporarily solve the problem, but a mass roll out (further statistically shared) would lead to an even bigger crisis due to CPE pricing and limited bandwidth offered by the wireless spectrum.

Unbundling of the local loop is required for real competition to result in the Indian broadband sector. Access to the copper network alone will not solve all the problems of the last mile because the quality of the copper, in terms of diameter and age, is also a question. In such a scenario, it might be worthwhile to investigate a combination of alternatives such as cable, fiber, wireless, and in particular, combinations (FTTC + wireless) to provide last-mile broadband connectivity. These alternatives also have their own set of problems. For example, cable (CATV) in India is chaotic, disorganized, and employs primitive technology. But its reach is vast. There are 78 million homes in India with cable TV [4]. If telecom companies join with multi-systems operators (MSOs)/last-mile cable operators and make appropriate investments, there is a huge opportunity to roll out cheap broadband services in the country. With wireless technologies such as WiMAX, there is always the problem of spectrum allocation, even though it must be noted that wireless has the potential of connecting rural and geographically dispersed areas. In rural areas where incomes are traditionally low, the affordability of broadband (even if it is available) is a problem limiting the use of wireless.

Copper wires have their limitations and must be seen as a temporary short-term solution. FTTH and FTTC is the long-term solution for broadband services. If triple play of voice, data, and video is to be offered to the Indian consumer, deploying fiber in the last mile is inevitable. Also, there are enough applications to justify its deployment. Applications such as video on demand, IPTV, telepresence, and online gaming require high bandwidth — naturally provided by the optical fiber. There is a huge demand for video services and IPTV in most parts of India that must be tapped, as well as fostered as the key enabler for next-generation information access. The cost of deploying FTTC is gradually decreasing, and today it is an affordable solution. Making the decision to roll out fiber in the last mile will prove to be a wise business move for service providers. The operational expenditure in maintaining a fiber-based network is far less than that of a copper network. It is important that Indian telecom companies start making major investments in deploying FTTH and FTTC with last inch (from the curb site to the homes or MTUs) using either cable or wireless. This will lead to convergence and propel demand for bandwidth and content. Providers will grow by offering new services through their advanced networks at affordable price-points. A high-speed access network also would make good use of the already deployed, but insufficiently used metro optical network. The metro network is a good facilitation of bandwidth to the access network.

As can be understood from the previous discussion, the high price of Internet in India is mainly due to lack of proper regulation, skewed competition, and mismanagement rather than technical constraints.

Pricing Philosophy

What beats the well-known demand-supply curve is the basic pricing philosophy. This pricing philosophy defies at a certain level, conventional wisdom — whereas demand all over the world for broadband is increasing, in India it is only flat or with luck, growing. This, despite the fact that the Indian economy is doing well. The pricing model used by ISPs in India for retail customers is the culprit for this situation [11]. All of the major ISPs in India employ a *usage*-based pricing model unlike the flat-rate pricing model that is prevalent in most parts of the world.

ISPs in India use a per-megabit pricing model. For each subscriber, an upper bound is placed on the total data transfer that the customer is allowed per month, for which a fixed fee is charged. For usage beyond the specified limit, the customer is charged for every additional megabit of data transfer.

Very few unlimited-usage plans are offered by Indian service providers. Moreover, the pricing of these select plans is high. A usage-based pricing model has been an impediment to the growth of Internet-related services in India. It deters price-conscious users from trying new content and services. It also is an obstacle to rolling out new products and services aimed exclusively at the Indian market for local Internet technology firms and content providers.

The flat-rate pricing model has advantages for both service providers and retail customers. Service providers save the overhead of deploying a system for tracking and billing usage. In fact in principle, a system that implements a usage-based model can lead to intrusion of privacy with techniques such as MAC binding and static IP allocations. With a flat-pricing model, the ISP knows the amount of payments it will receive from its subscribers and can budget accordingly. For retail customers, this model provides convenience and a predictable fee. In the developed world, many content providers and online communities have blossomed through consumers having free choice, that is, allowing consumers freedom in the choices they make without worrying about per-megabit download prices. The flat-rate pricing model has been an important factor in the growth of the Internet. It has enabled the Internet to become a kind of online public library where one can find information for free. Therefore it is an opportune time for the regulatory authority to make an impact by delicensing the landing points, thereby making international bandwidth cheap, and doing away with usage-based models. In fact, due to the presence of state-owned ISPs, the state is in an excellent position to bridge the widening digital divide, thereby setting an example and also lowering the price of broadband.

One can also argue against the usage-based bandwidth price model as something that sells information that is available on the Internet for free! The flat-price model is well justified as one in which the ISP charges the customer for the network (the CAPEX and operational expenditure [OPEX] that the ISP invests) and not for the content (or amount of content) in the network.

The data transfer in a usage-based model is typically at the data-link layer (frame-transfer) — hence the consumer pays for protocol packets in addition to actual data. This pricing model has its problems. Users may be charged for information they do not want or did not request. For example, spam, pop-up advertisement windows, and video advertisements that precede the actual video. Also most Web sites today have rich graphics and multimedia content, which means the user would pay high access fees.

The prime argument against usage-based or time pricing is that it limits the user from exploring the services and information available on the Internet. A subscriber is less likely to surf the Internet when a background counter is ticking. This makes it difficult for content providers to attract Internet users who are shy of using bandwidth-heavy services such as video-on-demand, streaming media, online gaming, and teleconferencing, for fear of being charged excessively. It can be concluded that usage-based pricing is jeopardizing the growth of the Internet in India as it results in monetary disincentives for producers and consumers of content and services.

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A fiber-based last-mile infrastructure coupled with islands of wireless connectivity would ensure cost-effective access to information and eventually facilitate an increase in the GDP of the country, contributing to growth, and partially alleviating energy problems through reduced transportation.

Conclusion

The growth of broadband in India has been impeded because of high prices, a flawed pricing model, and weak demand for Internet-related services. An artificial shortage of international bandwidth, poor network operations, and difficulties with the last mile have led to the high cost of bandwidth in India despite a decent metro and core networking infrastructure. The usage-based pricing model has not allowed content or demand to grow. Localized content is unavailable resulting in low demand for Internet connectivity by retail customers. Hence, we have a scenario where the growth of the Internet in general, and broadband in particular, has slowed down. Unbundling the international cables, better peering by ISPs, and competition through regulation will decrease the price of bandwidth in India, propelling the much needed increase in broadband demand. Employing the flat-rate pricing model will increase demand for content and services. These steps will enable broadband to grow at a rapid rate in India.

A country that added 15.6 million mobile (cellular) [12] subscribers in the month of March 2009 has a very low broadband penetration rate. Likewise, 78 million homes have cable TV. These two growth areas (cellular and cable) clearly show that whenever localized operations are possible, the price structure is there to sustain it, whereas whenever the operations require global interconnection, the pricing structure fails. Cellular pricing in India at 2.5 cents a minute, with no pricing restrictions on incoming calls, makes it one of the lowest in terms of cost of ownership. Similarly, most cable users pay less than five dollars a month for all cable channels, which in the Western world cost $50 per month. Our observation is that urban India is geared more toward television as an information tool than the Internet, implying that choice in terms of content is a secondary consideration.

The localization and fixed-bandwidth transfer of cellular traffic and the in-home availability of cable content enables mobile and cable operators to aggressively price these services, thus resulting in unprecedented growth. The question, then, is why the same cannot be implemented for broadband?

Although physical infrastructure is hard to improve, it is certainly possible to improve the information infrastructure, in particular the last mile. A fiber-based last-mile infrastructure coupled with islands of wireless connectivity would ensure cost-effective access to information and eventually facilitate an increase in the GDP of the country, contributing to growth, and partially alleviating energy problems through reduced transportation.

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