# LCD-Net: Lowest Cost Denominator Networking

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## ABSTRACT

"The Internet is for everyone" claims Vint Cerf, the father of the Internet via RFC 3271. The Internet Society's recent global Internet survey reveals that the Internet should be considered as a basic human birth right. We strongly agree with these and believe that basic access to the Internet should be made free, atleast to access the essential services. However the current Internet access model, which is governed by market economics makes it practically infeasible for enabling universal access especially for those with socio-economic barriers. We see enabling benevolence in the Internet (act of sharing resources) as a potential solution to solve the problem of digital exclusion caused due to socio-economic barriers. In this paper, we propose LCD-Net: Lowest Cost Denominator Networking, a new Internet paradigm that architects multi-layer resource pooling Internet technologies to support benevolence in the Internet. LCD-Net proposes to bring together several existing resource pooling Internet technologies to ensure that users and network operators who share their resources are not affected and at the same time are incentivised for sharing. The paper also emphasizes the need to identify and extend the stakeholder value chain to ensure such benevolent access to the Internet is sustainable.

## Categories and Subject Descriptors

K.4 [Computers and Society] C.2.1 [Network Architecture and Design]: Wireless communication; C.2.2 [Network Protocols]: Protocol Architecture; C.2.6 [Internetworking]: Standards.

## Keywords

Internet, Digital Inclusion, Less-than-Best Effort, Free

## 1. INTRODUCTION

The Internet is heralded as the eighth wonder of the world connecting 2 billion people around the world. With the profound success of mobile phones (it is estimated that 5 billion people have mobile phones) the "connected" world is expected to get bigger and bigger. Internet has crossed new frontiers with access getting faster and cheaper. New applications and services are being offered – and their impact omnipresent.

Vint Cerf in his informational IETF RFC 3271 states: "The Internet is for everyone - but it won't be if it isn't affordable by all that wish to partake of its services, so we must dedicate ourselves to making the Internet as affordable as other infrastructures so critical to our well-being" [1]. The Internet Society's recent global Internet survey reveals that the Internet should be considered as a basic human birth right. The survey also revealed that the Internet would play a significant role in solving global problems, including reducing child mortality, improving maternal health, eliminating extreme poverty and hunger, and preventing the trafficking of women and children [2].

However many individuals find themselves unable to get basic Internet access. Some may not be able to get it due to lack of infrastructure support (which accounts to the notion of digital divide problem faced by most people in developed countries). There have been significant initiatives to solve the problem of affordable infrastructure. In the UK, the government's current efforts to address digital inclusion have focused primarily on allocation of £530m to subsidise industry deployment of both 'superfast' broadband to urban areas, and 'standard' broadband to more remote locations [3]. This approach is predicated on a desire to support novel digital economy services through improvements in speed for urban users, while simultaneously ensuring basic levels of access for all.

Crucially, most of these approaches address infrastructural barriers without addressing economic ones. Addressing digital exclusion due to socio-economic barriers is important. The United Nations revealed the global disparity in fixed broadband access, showing that access to fixed broadband in some countries costs almost 40 times their national average income [4]. This problem is also applicable to developed countries where many individuals find themselves unable to pass a necessary credit check, or living in circumstances that are too unstable to commit to lengthy broadband contracts. Indeed, Internet services are increasingly accessed on the move and so current models of "roaming" access provision drive this economic exclusion to a new level, not currently addressed by the push to deploy broadband. A recent survey [5] revealed that affordability is cited as the primary barrier, explicitly so by over 22.7% of digitally excluded 16-44 year olds.

We believe that basic access to the Internet is a fundamental human right like clean water, public roads, school etc, because of its societal benefits (like education, employment, health, connected society etc). Countries like Finland, Estonia, France and Greece have already passed laws recognising the Internet as a human right. We believe that leaving connectivity for all to be governed by market economics is a major impediment to achieving the full benefits of the Internet, and that basic Internet access should be made freely available to all due to its societal benefits, a sentiment recently expressed by Berners-Lee [6]. The current economic models for accessing the Internet builds on the basic Best-Effort model (which would be a paid user's basic

Service Level Agreement (SLA)) and the transport protocols that govern the transmission of data were adapted to suit the Best Effort nature of the Internet to contend for available resources, hence making it virtually impossible for enabling free Internet access.

Through this paper, we are hoping to break the current mould of thinking that law of economics should govern connectivity to all. We believe that the Internet (atleast the essential services) should be made freely available to all to reduce the digital divide due to socio-economic barriers. We propose to do this through the following (which is the contribution of our paper):

1. Encourage donated benevolence that will enable sharing of resources (unused capacity such as users sharing their home broadband connections or their mobile Internet or network operators giving away their unused capacity). We propose Lowest Cost Denominator Networking (LCD-Net), a new Internet paradigm that architects multi-layer resource pooling Internet technologies that would enable the notion of Internet benevolence which we believe could greatly reduce a network operator's direct investment in local infrastructure to support wider Internet access. LCD-Net proposes to bring together several existing resource pooling Internet technologies to ensure that donors (users and network operators) who share their resources are not affected and at the same time are incentivised for sharing their resources.

2. Extend the stakeholder value chain by including more than the two traditional parties (consumer and internet service provider). New business models that allow governments, charities etc, the option to buy or pay for access (and become virtual network operators) must also be encouraged. This would in turn reduce operating expenditures for network operators. Such addition of third parties as stakeholders can give a multi-faced value chain where there is mutual benefit akin to commercial examples such as content delivery networks, which benefit from more users.

The rest of the paper is structured as follows: Section 2 discusses the LCD-Net paradigm, Section 3 talks about the stakeholder value chain and Section 4 discuss the social and policy challenges and finally we conclude the paper.

## 2. LOWEST COST DENOMINATOR NETWORKING

Although there is no single magic bullet to remove socio-economic barriers, there could be technological solutions that could drastically reduce these barriers. The research community should encourage, identify and architect new modes of access that could increase the efficiency of the usage of existing communication resources, enhance cooperation among operators, cooperation among end users, improving access and accounting and enable "sponsoring" of access to communication.

We put forth a proposal to the research community called the Lowest Cost Denominator Networking (LCD-Net), a new Internet paradigm to architect or bring together multi-layer resource pooling Internet technologies to support new low-cost access methods that would enable benevolence in the Internet. LCD-Net proposes to use resource pooling at many levels such as:

1. Efficient wireless spectrum use (through network coding [7], multipath, joint multi-user beamforming [8], MIMO, radio resource management, FatVAP [9]).
2. More efficient network use through use of caches and multicast (Information Centric Networking [10]), which can reduce transmission of redundant traffic and reduce the average transmission cost per service access.
3. Enabling delay tolerant/opportunistic offloading (e.g. Haggle [11]) access to improve access.
4. Making use of the available unused capacity in broadband networks by mandating Less-than-Best Effort (LBE) also known as the Scavenger access [12][13] (lower priority service compared to the standard Internet service offered to paid users or use scavenger transport protocols/methods that transmit data only when the network is under-utilised) to these resources. These access methods ensure that the donor who is sharing the resource is not affected in terms of performance.
5. Social networking support for enabling automatic creation of mesh (with other users or devices [14]) with energy offloading capabilities [15].
6. Support for DNSSEC, RADIUS, Shibboleth, Secure Open Wireless Access (SOWA) [16] etc.

These technologies currently exist in all forms (standards, successfully deployed, research and development phase etc)– LCD-Net brings together several of these Internet technologies to ensure that donors who share their resources are not affected and at the same time are incentivised for sharing their resources thereby creating new access methods that could potentially solve a social problem of digital exclusion.

We illustrate few ways on how these different technologies could fit together to enable free Internet connectivity.

**Home users sharing their Internet connection:** The first solution requires a community-wide participation where broadband customers can volunteer to share their high-speed broadband Internet connection for free with fellow citizens. There are schemes that allow you to do this (for e.g. see BT FON [17]). Although these methods are gaining worldwide acceptance, they are usually viewed as an extension of a user's paid service. We believe that this service could be made as a free service when users are allowed to access these WiFi access points using LBE access [18][19]. These methods would allow a user to use a shared link without affecting or competing for the resources of donors who have shared their Internet connection. Such resources could be used to access essential services such as transmission of vital health monitoring data, sensor data, government services etc [19].

It is important that network operators support this by enabling QoS differentiation at the Broadband Remote Access Server (BRAS). By enabling LBE, the traffic from the free users should not affect the paid user's traffic, which are marked higher priority by default. It could be also interesting to see if we could use LBE based transport methods for the free users to access these shared access points (for e.g. Low Extra Delay Background Transport (LEDBAT) [20] type methods). These new transport methods that are currently being standardized at the IETF would enable users to share a resource without competing for the shared resource. It

would be interesting and challenging for the research community to explore and enable applications such as web (which currently need Best-Effort (BE) service) to work with methods such as LEDBAT and other LBE transport/network access.

Another option would be to enable these WiFi access points to be Delay Tolerant Networking (DTN) [21] enabled. This enables free users to use asynchronous communication by offloading data into these WiFi APs. The WiFi access points can then wait to see if the connection is idle and then transmit the bundled data either using LBE QoS (if enabled) or use scavenger transport (for e.g. LEDBAT) proxies if QoS is not enabled. This also requires that network operators enable their BRAS to support these types of methods.

**Network operators distributing the unused capacity:** Internet Service Providers (ISPs) dimension their networks based on peak load often reflected in the 95-percentile pricing scheme [22]. The transit ISPs use such a pricing scheme to charge their customers according to peak demand. This is done to ensure that the QoS requirements of interactive traffic are always met. Past work [23][24] have shown that typical ISP traffic exhibit diurnal variation in which load peaks between the afternoon and night. Access ISPs usually pay according to the few hours of peak load. Such diurnal patterns combined with 95-percentile pricing leave large amounts of off-peak unused transmission capacity that can be used at no extra transit cost. Past work [25] has shown that by taking advantage of already-paid-for off-peak bandwidth resulting from diurnal traffic patterns and percentile pricing, delay tolerant asynchronous bulk data (in the order of several terabytes) can be transferred effectively without incurring any transmission cost to the ISP.

A potential solution would be for network providers to pool their unused capacity and distribute it to communities for free Internet access. Economic models that facilitate users to use the Internet during less busy times (for e.g. during night time) currently exist. However, these models are still expensive to users who cannot afford to pay for Internet access. We need to engineer new methods that would allow network operators to distribute their unused capacity. Networks such as two-way satellite or WiMAX that are based on Radio Resource Management (RRM) have an inherent ability to provide such a system. The method of asking for capacity and being granted capacity (RRM) provides the feasibility of engineering a system that could provide free access to communities by distributing the unused capacity. For instance in the two-way satellite network, the satellite network operator could provide the notion of unsubscribed terminals which can be connected to the satellite network. These unsubscribed terminals can then request for capacity when they have data to send. However, the Network Control Center (NCC) or the Hub would only grant capacity when there is a portion of the unused capacity that could be distributed over several of such terminals. In such a case, the time between requesting for spare capacity and being granted capacity may be high depending on current usage levels (on the order of several seconds, minutes or sometimes hours) bringing in the notion of a disconnected network. This introduces challenges to most of the current Internet applications that run on TCP as TCP is fundamentally limited by delay. Hence we have to engineer new ways of access to the network (for e.g. DTN access). Although such a system introduces asynchronous connectivity, by utilising existing GSM connectivity (reverse SMS's are usually free), by introducing efficient caching of data or location specific caching and by supporting localized Internet access (for e.g. the Haggle architecture [11]), we should be able to provide a communications medium free of cost to those who cannot afford Internet access until they are in a position to get better access to always-on Internet connectivity.

**Emergency Communications:** The notion of benevolence works well during emergencies (for e.g. a natural disaster) where people are ready to help each other [26]. Devices equipped with LCD-Net would be ideal in such a situation where people can share their resources for e.g. sharing their mobile phone for resources (energy offloading [15]) during energy constrained environments or devices are equipped to either open up their network, automatically mesh with devices of other users or personal devices [14] based on online social networking trends (for e.g. earthquake or tsunami in the area).

These solutions now raise interesting questions, which need to be addressed:

1. As a starting point, it would be of real interest to the research community to study how users use these home broadband routers and understand how much broadband capacity is available. Recently there has been a spate of work [27][28] on measuring broadband performance which could be a starting point for the research community to understand how much spare capacity is available that could be potentially shared.
2. We need to understand how and what sort of network techniques are required to identify free user traffic and how should the network react to contention/interaction at the network devices between traffic from donors, free users and other paid customers who are non-donors for e.g. what is the cost of displacing other paid user packets? This may raise QoS challenges and the need to throttle data usage/rates of users. However contrary to [29] which argued that the bottleneck in the Internet moves around over time from the edge, to the core, from the client side to the server side, and back again, the economics in the last decade seem to have led to a fairly consistent position where the metro, core, data center and server side are fundamentally overprovisioned, and scale out (i.e. stay that way as the world gets more connected and more people come online). We believe that what we have now is no longer "best effort" but an implicit Service Level Agreement (SLA) where the SLA is the Digital Subscriber Line (DSL) uplink/downlink speed. A user can get upto whatever the TCP, VOIP or IPTV session manages to grab. This is important and relevant because a lot of the time, the Internet is under-utilised [23][24], and by using techniques such as LBE we can ensure that the free LCD-Net user does not affect paid users who are sharing their network connections.
3. We need to identify how to support effectively different service classes, with authentication, authorization and accounting (AAA) for different traffic or service types with special regard to the free service/Internet users. One potential solution would be to enable registration of users via government bodies. Technologies such as RADIUS and Shibboleth could be used to grant permission to access the resources.

4. Any proposed solution has to be scalable, feasible and most importantly sustainable. This now raises the need to identify the stakeholder value chain.

## 3. THE STAKEHOLDER VALUE CHAIN

We know that there is no such thing as free lunches. We argue that the stakeholder value chain must be extended for incentivizing donated Internet access by including more than the two traditional parties (consumer and internet service provider). One example would be adding the local government, who have a vested interest in decreasing the cost of human-centered service, and replacing these costly interactions with online services, which already prove popular with existing Internet users. Achieving universal access would create new opportunities for the government for e.g. in the UK, it is estimated that the 'digital by default' programme could achieve an annual savings of £2.2bn [30].

New business models must also emerge that allow governments, charities etc, the option to buy/pay for access. This would in turn reducing operating expenditures for network operators. In this context it is important to explore new economic models and incentives that will enable such approaches to be economically justifiable, feasible and sustainable. We list down a few below:

1. Apart from the charitable act there is a moral responsibility for network operators to be responsive to public needs. The government could provide incentives to such operators by tax reductions and offering other benefits. There is a mutual benefit for both the government (to show that it is taking care of the welfare of the people) and the operators (who get additional perks).
2. The solutions described here could give opportunity for charities/organizations to become virtual network operators by buying services from wholesale operators at a lower cost for lower quality of service (for e.g. buying the unused capacity at low cost). This provides better utilization of the resources and new avenues for revenues for operators. This also paves way for local councils/municipals to provide free Internet access at LBE without unfairly competing with incumbent providers and thus avoiding any litigious problems [31].
3. One compelling justification is that when access (low speed, low quality) is provided, users who cannot afford may see new opportunities and realise the benefits of the Internet. They might find a compelling need to improve on the level of service and which in turn can attract more customers (when they are able to afford). So the network operators can see this as giving free service to trial out their system and build brand loyalty apart from the government perks mentioned earlier. There may be other advantages for the network operators (for e.g. access to more user data for targeted advertisements). This in turn can enable network operators to provide discounts to users who share their Internet connection.
4. When more than two parties are involved in offering network access (e.g. neighbors allowing neighbors to piggyback on their wireless for some exchange) there does not necessarily have to be a direct quid-pro-quo. There may instead actually be advantages to pool resources at many levels, including more efficient wireless spectrum use ([32] suggests that a throughput of a wireless LAN can actually scale by adding more APs on the same channel). Based on the content centric argument [10], allowing more users to access the Internet enables more efficient caching at the edge nodes which in turn provides faster access to vital data (performance incentive to the user) and also reduces the need for unnecessary transmission of data over the network (cost incentive for the operator). Indeed, recent work in Cambridge and London has shown that an 85% reduction in iPlayer catch-up TV traffic can be easily achieved with relatively modest caching of content [33].
5. Donor's broadband connections could be used to transfer government and industry sensor data without the need for building new network infrastructure and new revenue models can be generated in such a way that donors are provided with financial incentives.
6. Enabling reverse payment models, where the service provider pays for access. This would introduce new ways of users subscribing to capacity where by default the user can get free Internet at lower capacity/rate to access government services.

## 4. SOCIAL AND POLICY CHALLENGES

Successful adoption of any proposed technological solution requires user acceptance and requires to be driven based on user need. Hence it is important to understand the social challenges that need to be overcome to realize the potential benefits of any proposed solution. Some of the challenges include:

1. Understanding the current practices of digitally excluded users (availability of devices, current means of accessing Internet services) and the Internet services they would value.
2. Understanding the current sharing practices of donors (both within and outside the home), and perceptions, motivations and expectations of the sharing resources by both donors and users.
3. Understanding the concerns of both donors and users (energy, cost, privacy, security, performance, digital plumbing issues etc).
4. Understanding the psychological plane of users who would be using the technology (for e.g. self esteem).

It is virtually impossible to solve the problem of digital inclusion due to socio-economic barriers without fundamental overhaul in government policies. Governments should change their policy to encourage these initiatives by providing incentives to network providers who distribute their unused capacity or allow their customers to share their capacity. Telecom regulators should be open for change.

One justification for why the government could change their policies to legalize initiatives where network operators must provide opportunities for free Internet access is that the operators not only rely on the government to sell the spectrum licenses but also depend on government help to launch their services. So it can be argued that the government can ask these operators to allocate a small percentage of their capacity to provide free Internet atleast to access the essential services.

In the UK, the government is working on the Open Data Initiative [34] where all the non-personal data that government agencies collect (crime, health, transport, economic stats etc) will be available to anyone who has Internet access. However people without Internet access will be deprived of this democratic right. Hence the government could ensure that the open data could be only available via network operators that offer lower quality free Internet access to urban and rural users on top of their normal higher quality service. This would create an incentive for network operators to deploy lower quality free Internet access.

Different countries have different telecom regulation policies. For e.g in the UK, the Ofcom has issued a warning as part of the Digital Economy Act to free WiFi providers that they will be held responsible for the actions of their users. This does not really make a distinction between an individual or a company providing WiFi free to the surrounding community as a gesture of goodwill against a company that does so to draw in the customers. We believe these measures will further broaden the digital divide between the connected and disconnected communities.

# 5. CONCLUSION

Through this paper, we try to address the problem of digital exclusion due to socio-economic barriers and propose that basic access to the Internet should be made free, atleast to access essential services. Our vision of digital inclusion is a wider goal that aims at expanding the Internet beyond what is currently economically viable with current business and technology models. The goal is wider and includes all aspects of larger participation in society.

In this paper, we propose Lowest Cost Denominator Networking (LCD-Net), a new Internet paradigm that architects multi-layer resource pooling Internet technologies into a single architecture than can span over a variety of connectivity options that is larger than today's set of choices. LCD-Net would allow new modes of free access for e.g. network operators distributing unused capacity to deprived communities or users sharing their broadband connection with other users. LCD-Net could greatly reduce a network operator's direct investment in local infrastructure to support wider Internet access.

There are both research and policy challenges to the realization of a future Internet capability that will offer appropriate access to all parts of society. In contrast to the way the current Internet has evolved, the development of the next generation network will demand both collaboration and a shared vision between researchers, corporations, community groupings and governments. It is virtually impossible to provide the notion of free connectivity without identifying the stakeholder value chain. Hence the paper also emphasizes the need to extend the stakeholder value chain by including more than the two traditional parties (consumer and internet service provider), for example, adding local government. We also need to identify the social challenges as well as new economic models, such as offsetting provisioning of content with caching for future usages, usage of under-utilised parts of the network etc. to enable these proposals to be feasible and sustainable. Telecom regulators should support this change. Governments should change their policy to encourage these initiatives.

We would also like to stress an important point: as network access speeds increase in the future, today's Less than Best Effort service would be tomorrow's Best Effort service. So it is better for the research community to start thinking about this sooner than later and encourage new initiatives in the directions mentioned in this paper.

We conclude this paper by saying that when a butterfly's wing can set off a cascade of atmospheric events why cannot congestion control and QoS save human lives? We hope this paper encourages a new line of thinking – to adapt and bring together existing technologies to create new models of access and solve a societal problem even to the extent of saving lives. We end by quoting Vint Cerf – "Internet IS for everyone - but it won't be unless WE make it so".

# 6. ACKNOWLEDGMENTS

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