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Intended status: Informational	December 1, 2014
Expires: June 4, 2015	

Tools to accomplish the goals of GAIA (Global Access to the Internet for All)

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Abstract

This document explores the central problem of the GAIA (Global Access to the Internet for All) IRTF research group. It discusses several possible approaches or tools that can be used to increase the number of people with access to the Internet. Specifically we discuss how these tools can improve reach, reduce cost, and improve the quality of the Internet, especially in underserved areas.

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1. Introduction

GAIA aims to increase availability of access to the Internet. The author will discuss a number of tools available to different actors to accomplish this goal. For each tool, the author will consider three related attributes of availability: reach, cost, and quality. Reach is which members of a population could access the Internet via various approaches. Reach is not just a technical characteristic. Services which have various administrative requirements (ex: long-term contracts, legal residency, requirements for certain forms of identity) also restrict reach. Cost is the overall cost to the end-user for the services they would like to use. It includes upfront and recurring subscription or usage costs. Quality is related to the useful throughput for the services the end-user would like to use. Factors affecting quality include bandwidth capacity, latency, jitter, congestion, loss, and the reliability (downtime) of the service. The author will also consider which actors has the ability to implement which of these tools.

2. Recommended tools to improve Internet availability

2.1. Encourage competition

History has shown that Internet markets with lots of providers are robust, healthy, and provide a full range of services and prices, including very affordable basic service. By contrast, markets with monopolies or duopolies tend to experience high prices and often poor quality. This is not uniquely a problem in developing countries. For example, at the time of this writing most residences in the United States only have access to a single cable TV provider and a single telephone provider for Internet access. Relative to other countries at a similar level of development, residential Internet access is among the most expensive and slowest among other rich countries. One area where competition has dramatically lowered cost quite suddenly is in access to ocean-going fiber. Where some markets (much of West and Southern Africa, Haiti) went from a single fiber landing with access to the Internet to more than one, the costs dropped by at least an order of magnitude in a few years.

Encouraging competition is about removing unnatural or unnecessary barriers to new entrants. This is not to say that telecommunications should be completely unregulated. Every form of wired or wireless Internet access needs to use some kind public resource (e.g. travel over public land or a public right of way, or transmit electromagnetic waves). In a competitive market this use is regulated to encourage fair access to established providers and new entrants alike, including non-commercial providers. The various approaches described as “Alternative Network Deployments” in [I-D.manyfolks-gaia-community-networks] all effectively offer an alternative to one or more “traditional” service providers and therefore are an additional form of competition.

A regulator can further implement policies that encourage providers to extend access into new or underserved areas rather than providing service in a location that already has several competitive providers. Two ways are to increase the cost of the spectrum or right-of-way in well-served areas, or to allow no new permits if there is capacity available from a neutral service or provider or from a certain number of providers (ex: four or more). For wireless services, allowing providers (private or community) in underserved areas to use frequencies without having to buy a country-wide license is especially effective at encouraging expansion of range. The use of dynamic spectrum (ex: TV white spaces, dynamic allocation of GSM frequencies) is a logical extension of this approach and looks particularly promising.

In many developing countries, there is a lack of good information about the size of the market in underserved areas. For example, in a regional capital you may have 3 or 4 mobile network operators offering service, but in a nearby small city you may find no service at all. Rather than use available capital to extend service into a new area, operators often add capacity in an existing area, because they can perform a break-even analysis with relatively low risk. One of the advantages of community-based approaches in serving a new area is that their goal is usually to serve a specific community at a reasonable cost rather than to select the most profitable or least risky project among many possible choices. The community is also in a better position to estimate the eventual usage than typical outsiders.

In summary, once a market becomes competitive, cost drops and quality improves. Reach usually improves somewhat slowly in the worst case, but this can be helped along considerably with appropriate policy choices, by allowing flexible or dynamic allocation of frequencies, and by encouraging communities to deploy their own networks.

2.2. Make services available with few barriers to entry

In many developing countries, anyone can buy an inexpensive mobile phone with basic Internet access and pre-pay for a “bucket” of bandwidth or unlimited Internet by the day, week, or month at very affordable rates. (Sadly this is not usually true in some rich countries.) By contrast, purchasing broadband Internet access may have several barriers.

For example Internet service may require filling out and signing a contract, possibly in a language that is not widely spoken by certain groups or economic classes. It may require having an official address or some form of official identification which is difficult or impossible for some segments of the population to obtain. For example, contracts in Haiti are typically in French even though the vast majority of the population are not able to read a complex document in French. Some large neighborhoods in India were built without permits and are therefore ineligible for addresses. In some countries, identity cards are routinely denied to certain ethnic groups. Services with these requirements are effectively out of reach of a large segment of the population.

Finally, if a service requires a large deposit, the purchase of expensive equipment, or a recurring financial commitment, this will affect the overall cost of the service and could exclude a large number of potential subscribers who could otherwise afford the normal usage or subscription costs most of the time.

2.3. Using existing copper or fiber more efficiently

This approach can reduce the cost and/or increase the quality (specifically bandwidth) of Internet links over existing copper pairs or fiber strands. For fiber, migrating TDM, SRP, FDDI or even SONET to Ethernet often increases the available capacity considerably. For copper, migrating POTS, ISDN, TDM, or DSL links to Ethernet or faster forms of DSL can also increase available capacity, but usually with slightly more effort. Ordinary POTS lines are typically not well conditioned, so copper may need to be touched at several points before it is ready to use.

2.4. Adding more fiber (or sometimes copper)

Fiber is a good long-term solution to improve the capacity and reliability of Internet services along a path. It can also be very cost effective if there is a competitive market for using the fiber. New fiber or copper can be deployed along a route or to a destination with no (non-satellite) Internet connectivity at all, it can replace an existing wireless link, or it can be an upgrade or replacement of an existing copper or fiber link. Replacing an existing congested terrestrial wireless link is often an especially good investment, as the wireless equipment can be redeployed to a location that has no connectivity at all.

2.5. Using existing wireless spectrum more efficiently

Unlicensed spectrum (typically the 2.4Ghz and 5Ghz Industrial Scientific and Medical bands) in populated areas can become quite crowded. Best practices include using directional antennas for point-to-point links and reducing the transmit power when possible.

Cellular telephones use a limited number of licensed frequencies which are typically allocated to mobile network operators on a per-country basis. Upgrading cellular data protocols from GPRS or EDGE to 3G improves the bandwidth efficiency. In areas with high usage, reducing the size of each cell improves density and bandwidth efficiency. These both improve the quality of available Internet. In areas with no cellular service, providing a new allocation to a community or provider without a nationwide license, or allowing them to reuse the frequencies of one or more nationwide cellular providers in the unserved area would allow for a tremendous improvement in reach.

In many developing countries there are relatively few broadcast television stations (often between 2 and 4), but a large amount of bandwidth is reserved for their potential use. TV White Spaces offers the opportunity to use the bandwidth on unoccupied channels for networking purposes. As frequencies for WiFi, WiMax, and similar wireless services are extremely limited, TV White Spaces can potentially offer lots of additional bandwidth for data services in a part of the wireless spectrum with excellent propagation characteristics. In general, dynamic frequency allocation could make a number of frequencies available to offer services in underserved regions.

2.6. Adding wireless connectivity where there is no service at all

2.6.1. Terrestrial wireless

Some form of Internet access is currently available in the following radio bands: High Frequency (HF, 3Mhz to 30Mhz), Very High Frequency (VHF, 30Mhz to 300Mhz), Ultra High Frequency (UHF, 300Mhz to 3Ghz), and Super High Frequency (SHF, 3Ghz to 30 Ghz). Each of these bands has different propagation characteristics.

Many HF frequencies are reflected by the ionosphere and can easily travel hundreds or thousands of kilometers. The amount of reflection varies depending on the time of day and season and can be subject to substantial interference. Unfortunately this band offers very low bandwidth and generally requires quite large antennas. It is the only terrestrial option for a user without line of sight who is hundreds or several tens of kilometers away from the nearest Internet access. Fortunately these regions are relatively few, primarily in open ocean, deserts, steppe, polar regions, and parts of central Africa.

VHF frequencies and the lower UHF frequencies generally travel slightly further than line of sight. They are frequently diffracted by hills and buildings. SHF and the higher UHF frequencies generally require near line of sight for reliable transmission. In general, the higher the frequency, the more bandwidth is available and the shorter the effective range.

Terrestrial wireless solutions include cellular data, WiFi, WiMax, TV White spaces, and packet radio (the last typically used for marine communication and by hobbyists).

2.6.2. Near-earth wireless

Several solutions have been proposed and deployed as trials where stations on the ground communicate with balloons, drones, or low-earth orbit satellites. These non-terrestrial signals still have a negligible latency relative to geosynchronous satellites (e.g. approximately 4ms round trip to the Iridium constellation of low-earth orbit satellites).

Balloons and Low-earth orbit satellites are launched once for the duration of their service life. Most uses of drones assumes that they will periodically return to earth for servicing. While this offers the possibility to easily upgrade telecommunications gear there is a long-term logistical element required for their use. One disadvantage of drones in some regions is their association with surveillance or military activities (including lethal action). The author observed that in South Sudan, the sound of particular aircraft will cause everyone to drop whatever they are doing and run for the bush.

Each of these solutions requires a rather large upfront investment, but depending on the size of the target service area, population density and difficulty of the terrain may still be more cost effective than terrestrial solutions. For example, low-earth satellites likely offer the best price-performance in ocean and polar regions. Balloons could offer a good balance of price-performance in sparsely population desert regions. Drones (if culturally appropriate) or tethered balloons could supplement capacity in disaster areas or dense refugee settings.

2.6.3. Geosynchronous satellites

Traditional geosynchronous bidirectional Internet (typically via VSAT or BGAN) is still the option of last resort for businesses or organizations in locations with no terrestrial broadband service and slow, unreliable or non-existent cellular data. BGANs are mobile and offer connectivity from practically anywhere outside with a view of the sky. (Geosynchronous satellites are not accessible from the polar regions.)

Unfortunately these service are relatively hard to setup, expensive to setup, and in places where they are most needed are often expensive to use. In addition, for some of their plans many providers place a cap (called a “Fair Access Policy” or FAP) on the maximum amount of bandwidth that can be consumed over some period of time (typically one month or one week). When this cap is reached the effective bandwidth drops well below 8kbps.

Unidirectional satellite access can provide bulk data or broadcasting to a large number of ground stations simultaneously. This could include for example educational content, entertainment, news, and software updates. In some cases, the subscriber can propose or subscribe to specific content using an out-of-band Internet connection.

2.7. Replacing (geosynchronous) satellite with lower latency services

Traditional bidirectional satellite Internet services (ex: VSAT or BGAN) use geosynchronous satellites which add a round-trip delay of at least 480 to 558ms to every packet. For interactive usage (ex: web browsing) or real-time communication the delay is especially bothersome. Likewise, cellular towers in remote areas often use a geosynchronous satellite for backhaul. (A call from between such towers will have a minimum delay of at least 1 second.) This attribute affects the quality of the connection.

As of this writing there were a handful of reasonably affordable (ex: around $100) satellite bidirectional Internet access options available in the United States. By comparison a similar speed satellite service in the Democratic Republic of Congo might cost ten times as much. Why is there such a discrepancy? Providers of satellite Internet service know that their service is often a choice of last resort. In countries with poor or expensive Internet access the Internet provider can raise the price of their service substantially. Because there is no or very little competition they know that the market will bear a much higher price for the same service.

Also, the regulator in each country usually collects fees for the use of satellites. If the service provider charges a lot for their service, chances are the regulator will charge a lot too, and that will be passed along to the end-user.

2.8. Increasing access to electricity

In many developing countries, power from an electrical grid is not widely available outside of large cities. Where a cellular network exists but the typical individual user does not have electricity, mobile phone users may leave their telephones with the guard of a the cellular tower or with a local entrepreneur for charging.

When setting up new wireless links in remote locations, the cost of providing power (either via a generator or solar system) usually exceeds the cost of the networking or cellular equipment. The author also lived in a town where the local cellular service was turned off at night to conserve fuel for the generator.

A reliable source of electricity for cellular towers, community WiFi, etc. decreases the cost of providing those services and often increases the quality (reliability) of services that would otherwise run on generators. Power availability for users allows end users to keep mobile devices with them more often and makes it practical to use more powerful and larger devices which consume more power.

In the absence of grid power, the extent to which both networking and end-user equipment (ex: computers, tablet, or phones) consume less power has a huge effect on their possible reach.

2.9. Data mule services

When there is no permanent Internet connectivity in a community, but regular transportation between a connected town and the community, a specially configured computer or even tablet can shuttle data back and forth between the two locations. Currently this is a very low cost solution but requires a lot of very technical setup and installation.

While data mule services alone provide perhaps the worst user experience and fail to provide the interactivity of the Internet, they can help prove a demand for Internet which can help with a business case for community-based or traditional provider, or justify a subsidy or grant. Users can also supplement very slow interactive Internet connectivity with data mule services for bulk data.

2.10. Replacing above ground wired services with underground wired services

Moving services running on copper or fiber from poles to buried coper or fiber (typically in conduit) generally improves the reliability of those services. Cables on poles are generally more susceptible to storm and earthquake damage, damage from vehicles, vandalism and theft.

2.11. Peering

(Border Gateway Protocol [BGP]) Peering among service providers (typically in a country or region) decreases the cost of Internet access by reducing the amount of money spent by each provider on transit outside the area, and improves the quality by reducing latency.

3. Which actors can use which tools

Tool	Regulat.	ISPs	Community	Users
Encourage competition	x	n/a	n/a	n/a
Fewer barriers	x	x	x	n/a
Make wired more efficient	n/a	x	x	n/a
Add new fiber/copper	n/a	x	n/a	n/a
More efficient wireless	n/a	x	x	x
Add terrestrial wireless	n/a	x	x	n/a
Deploy Near-earth wireless	n/a	x	unlikely	n/a
Use Geosync satellite	n/a	x	x	x
Replace (geo) satellite	n/a	x	x	x
Improve Electricity	x	x	x	x
Data mule services	n/a	n/a	x	x
Move wires underground	n/a	x	n/a	n/a
Peering	n/a	x	n/a	n/a

4. Security Considerations

As this document is concerned primarily with policy or layer 1 and 2, many of the traditional topics discussed in a Security Considerations section are not relevant. However, in a future version of this document we can explore how difference choices affect pervasive monitoring, privacy, and denial of service.

5. IANA Considerations

This document requests no action by IANA.

6. To Do

Add a lot of references.

Add discussion of security.

7. Informational References

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