In recent years, access to the Internet has become increasingly important for individuals’ and communities’ economic productivity, as well as improved access to goods and services, education, government services and more. Some in the developed world, including First Lady Michelle Obama [1], have even begun to refer to Internet connectivity as a universal right.

In reality, however, Internet access is very far from universal. As of 2013, 4.4 billion people — over 60% of the world’s population — were not connected to the Internet [2]. And, while Internet penetration is increasing, the rate of its increase has slowed slightly, from around 15% a year in the mid ’00s to around 10% in the late ’00s. If this trend continues, over half the global population will still be offline in 2017 [2].

Facebook founder Mark Zuckerberg has repeatedly called this global digital divide “one of the great problems of our generation” [3]. And, in one way or another, overcoming this lack of Internet access is the focus of many ICTD initiatives, whether they aim to increase Internet access directly (e.g., First Mile Solutions’ drive-by DakNet) or simply compensate for its absence (e.g., EduPaL’s adaptation of the MOOC concept to offline use via USBs). While making affordable Internet access universally available is no panacea for global poverty, there are many reasons to believe that many of the 4.4 billion people without Internet access would benefit from access to it.

Barriers to Universal Internet Access

Just who is this “offline population”? As Figure 1 shows, the vast majority live in developing countries. However, Internet access is not universally accessible in developed countries, nor universally inaccessible in developing ones. Figure 2 shows many other factors that affect Internet availability, from McKinsey & Company’s landmark report on the digital divide [2]. The data is based on the 20 countries with the largest offline populations, where 75% of offline people (and just over 70% of all people) live.

McKinsey found that people lacking Internet access are very likely to be low-income and to live in rural areas, which are of course less likely to have access to network infrastructure and consistent electricity.

They are also somewhat more likely to be female and elderly than the online population. And, unsurprisingly, nonliterate people are very likely to be offline — although the literacy rate of the offline population varies widely, from 38% in Ethiopia to 99% in Russia [2].

McKinsey outlines four broad obstacles that impede global Internet access: incentives, affordability, user capability and infrastructure.

Incentives refers to the fact that many of the offline population

![Fig 1. In developed countries, more than 3/4 of people are online; in developing countries, that figure is under 1/3. Source: http://www.itu.int/en/ITU-D/Statistics/Documents/statistics/2014/ITU_Key_2005-2014_ICT_data.xls.](image1)

![Fig 2. Demographics of the offline and online populations. Source: [2].](image2)
are not as eager for Internet access as one might expect, either because they are unaware of it, because the Internet lacks resources relevant to them, or because the Internet is not highly regarded in their locale. To give one small example, in the United States, one compelling reason to use the Internet is to access the wide array of goods on Amazon. In many Middle Eastern countries, where Amazon doesn’t deliver and using a credit card online is seen as very dangerous, the Internet provides tangibly less value in that sphere.

The second barrier to Internet adoption, **low incomes and affordability**, is perhaps a more significant one. According to [4], “for 2/3 of people in the Southern hemisphere, the average monthly Internet access cost exceeds the average monthly income for someone living in that country.” While the cost of Internet access has dropped significantly in the last year or two, it still remains out of reach for a vast number of people. Furthermore, as [2] points out, the price of a data plan is not the only cost of going online. Smartphones are still very expensive in many countries; in Bangladesh and Vietnam, for example, they cost more than 20% of per capita income [2]. The cost of keeping the phone charged is also often prohibitive; in off-grid parts of sub-Saharan Africa, keeping a smartphone charged all month costs as much as a monthly data plan [2].

The McKinsey report’s third barrier to Internet access is **user capability**, which includes digital literacy but also, and more fundamentally, linguistic literacy. Assuming that 100% of the online population is literate, McKinsey used the overall literacy rates of the 20 countries surveyed to compute the literacy of offline users, and found that it was only 72%.

The final barrier to Internet access is **infrastructure**. One factor that has led to rapid installation of broadband connections in developing countries (besides high per-capital income, of course) is the high rate of urbanization. In less urbanized developing countries, and even in rural parts of developed countries, wired connection are prohibitively expensive to install.

In much of the developing world, the Internet is more often reached via a mobile phone and wireless connection than a computer and fixed-line broadband connection. However, this is only possible with 2.5G mobile coverage or better. According to Ericsson, 95% of the global population has 2G signal, but only 60% has access to 3G. McKinsey estimates that 1.2-2.8 billion people therefore lack the network coverage necessary for even basic Internet access [2].

Not only Internet infrastructure itself but also various types of “adjacent infrastructure” are necessary for Internet connectivity: reliable electricity, paved roads, and so on. Only 24% of sub-Saharan Africans have access to electricity; in India, only 55% of rural households have electricity. Power infrastructure is therefore a basic concern impeding the expansion of existing mobile networks.

McKinsey found that all four of these Internet barriers, as well as the 25 indicators they used to measure them, were strongly correlated both with each other as well and with Internet penetration rates. They suggest that coordination will be necessary to address many factors simultaneously, since fixing only one of these problems will not be enough to make Internet access universal.

**Last-Mile Solutions**

Improving infrastructure, McKinsey’s fourth barrier, has been a major focus of many international efforts in recent years. In particular, much discussion has focused on “last-mile solutions” — the infrastructure necessary to get connectivity from already existing Internet backbones to potential customers who are difficult to access, particularly in rural and/or remote areas.

In developed countries, familiar last-mile technologies include telephone lines for dial-up, ISDN and DSL, cable, and fiber optic cable. Each of these options connects a household or neighborhood to its Internet provider. However, all of these options are extraordinarily expensive to install, particularly in sparsely populated areas. Developing countries have therefore “leapfrogged” wired connectivity in favor of wireless solutions—mobile phones and satellite television. While this has significantly decreased installation costs compared, even wireless connectivity is too expensive to provide everywhere.

As Mark Zuckerberg said in a *Wall Street Journal* editorial, “the vast majority of data costs go directly toward covering the tens of billions of dollars spent each year building global infrastructure to deliver the Internet. Unless this becomes more efficient, we cannot sustainably serve everyone at prices they can afford. And unless we change this, we will soon live in a world where the majority of people with smartphones use them offline and still don’t have access to the Internet” [5]. Because of this, many
companies are now seeking more creative solutions to solving last-mile problems, through use of new technologies such as High-Altitude Platforms.

**High-Altitude Platforms**

In the late 1990s, two types of wireless Internet—terrestrial and satellite-based—were both in their infancy: the first Internet-enabled mobile phone, the Nokia 9000 Communicator, had just been produced [6], and several companies, most notably Teledesic, were vying to implement the first satellite-based Internet platform [7]. Both terrestrial and satellite Internet platforms seemed promising, yet both had significant drawbacks. While terrestrial wireless networks are quite low-latency and easy to use, they require the deployment of base stations every few kilometers (or more, in cases of terrain shadowing). Satellite Internet overcomes this difficulty, but has a long list of drawbacks of its own: it requires specialized equipment to receive; reception is generally only available outdoors; it has considerable propagation delay; tracking satellite motion adds significant complexity; service can’t start until the entire system is deployed; and increasing system capacity requires launching new satellites [8]. In short, it would be extraordinarily expensive to provide worldwide wireless Internet access using either terrestrial or satellite wireless networks.

High-Altitude Platforms (HAPs) offer a middle path. They broadcast wireless Internet not from the ground, not from satellites, but instead from aeronautic vehicles, such as dirigibles or unpiloted drones, in the stratosphere—about twice as high up as commercial planes. It was (and is) hoped that this intermediate solution would avoid the most serious pitfalls of both terrestrial and satellite-based networks. Unlike terrestrial networks, HAP networks don’t require ubiquitous base stations; unlike satellite networks, they can be accessed through regular devices, without propagation delay, indoors or out. Furthermore, HAPs can be stationery, decreasing complexity compared to satellites, and the network can be built piecemeal as demand grows. Because of this, “HAPS provides substantial advantages over terrestrial and satellite systems” [9].

By the late 1990s, several attempts had been made to deploy small-scale HAP networks. Jet Propulsion Laboratories experimented with pilotless planes that could fly for weeks without landing; other groups experimented with more traditional piloted planes flown at twice the usual altitude. Skysat and Av-Intel collaborated on an unmanned dirigible intended to hover over a single location for up to several months. Israel, NASA and the Japanese Ministry of Telecommunications all had HAP projects underway by 1997 [6]. The most developed plan at that time was Alexander Haig’s SkyStation, which went as far as securing the rights to previously unused airwaves for its planned 250 11-ton dirigibles in fixed positions at an
altitude of 100,000 feet [10]. This plan was never realized.

According to a 2005 survey of High-Altitude Platforms [11], there are three broad categories of HAP: unmanned airships, unmanned aircraft, and manned aircraft. Unmanned airships (see Figure 3) are enormous (~30 ton) balloons designed to stay within a 1 km cube for up to 5 years. They are environmentally friendly, running on solar cells and/or fuel cells, but can’t be relocated in emergency situations. Unmanned aircraft (see Figure 4), in contrast, are 1-ton winged vehicles that can stay within a 1-3 mile radius for perhaps up to six months. They are also environmentally friendly, and able to change location in case of emergency. Finally, manned aircraft (see Figure 5) are moderately sized (~2.5 tons) planes that can be flown for 4 to 8 hours by a pilot; they are very mobile in emergency situations, but are not environmentally friendly, being fueled by traditional fossil fuels.

Project Loon

In 2011, Google entered the HAP domain by launching “Project Loon,” creatively named both for the balloons at the core of the project and also for the slang term for being crazy, foolish or farfetched. Project Loon is housed in Google X, the same lab that developed Google Glass and Google’s self-driving car; besides those more viable ventures, however, Google X is known for pursuing ideas that border on science fiction. Less successful projects include a space elevator and teleportation, which were shut down for being infeasible and physically impossible, respectively [12].

Before Project Loon, HAPs projects always centered around the idea of keeping a dirigible, balloon or other airship as immobile as possible, so that it could provide Internet access to a fixed geographical area. This involved either tethering the vehicle or using significant energy to counteract stratospheric winds. Google’s Richard DeVaul wondered if, instead of paying the high costs of trying to keep a high-altitude ship stationery, it would be possible to provide Internet coverage through a whole fleet of aircraft that drift overhead, but which are numerous enough that there’s always one within range — more like GPS satellites. Thus, Project Loon was born.

Each Project Loon platform is lifted by a 14 m.-diameter helium balloon. The balloon’s envelope is made of polyethylene plastic, allowing for “super pressure” — the technical term for a balloon that is filled with high enough pressure gas that it doesn’t deflate when the temperature drops [13]. The precise specifications of this balloon are still under development; the project website [13] says Project Loon uses a single balloon, and that gas is released from the envelope to descend, while Cassidy [4] says each helium balloon has an air-filled balloon inside, which can be inflated and deflated to change elevation. Either way, the balloons are capable of rising or...
falling within the stratosphere. Since winds in different levels of the stratosphere blow in different directions, changing altitude allows the device to be steered in the desired direction. Thus, Project Loon doesn’t fall neatly into any of the three categories of HAP; it’s neither an airship nor an aircraft, and it doesn’t attempt to stay in one location over time.

The balloon’s payload consists of a Styrofoam box about the size of a beer cooler. Again, Google is tight-lipped about the precise specifications of the electronics inside, but it does reveal that each box contains (a) radio antennas to communicate with base stations, other balloons, and devices seeking internet, up to a range of about 40 km, (b) the processing power to run the balloon and communicate with Google, (c) lithium ion batteries to store power for night use, and (d) a fan (at least in the case of the two-envelope setup) to inflate and deflate the inner balloon containing air [4], [123].

Finally, the box is either surrounded or capped by an array of solar panels capable of producing 100 Watts in full sunlight. This powers the electronics and fan, and charges the batteries for overnight usage.

The basic structure of the Project Loon network is that Internet connectivity flows from a base station to any balloon within 40 km (horizontal distance) away. This balloon can then “beam” its connection to any other balloons within 40 km. The connection can currently make “hops” between five balloons. This means base stations are required approximately every 200 km, instead of every few km as in the case of cell towers; Google claims this should increase to about 1000 km within the next few years.

Each balloon then broadcasts Internet to enabled devices within its range, which is claimed to be a circle with a 40 km diameter in [13] and with a 40 km radius in [14]. In early tests, this broadcast was done using ISM radio bands (at 2.4 and 5.8 GHz), which required devices connecting to Loon’s services to have special antennae. More recently, they seem to have switched to LTE protocols, which are accessible through unmodified cell phones and (for non-mobile devices) through fixed antennae [15]. The speeds offered by Project Loon have also evolved over time; in early 2014, Cassidy called Loon’s Internet “single-digit megabits per second,” comparable to 3G [4]. By the end of 2014, the project claimed “5 megabits per second to mobile phones, or a zippy 22 Mbps to fixed antennas” [15], and by March 2015 the claim had escalated to “about 10Mbps downloads” [14]. Upload speeds have not been disclosed.

Covering the entire Earth with Internet with this configuration would take millions of balloons, as well as an infeasible number of base stations. However, the fact that the balloons can be steered drastically reduces the number of balloons needed — down to “tens of thousands,” according to Cassidy [4]. While balloons must generally stay at the same latitude as they rotate the earth, they can be steered toward or away from certain locations, and they can be encouraged to move slowly over land and quickly over the ocean. Google has already developed fleet planning software to plan flight paths for that number of balloons, including planning for the balloon’s energy constraints [4].

Although Project Loon is still very much in its infancy, it has enjoyed several successful test runs. The team’s first test balloon was launched in April 2012 and flew approximately 100 km over the Central
Valley of California before landing four hours later. In June 2013, a fleet of 30 balloons were tested together in New Zealand, successfully demonstrating that the balloons could be steered to maintain a distance of under 40 km from each other [4]. A year later, test launch in Brazil successfully tested broadcasting LTE coverage, from base stations connected through both fiber and 3G.

Since its inaugural flight in April 2012, Project Loon’s stats have improved impressively. As seen above, Google now claims faster connections and wider range than they did only a year ago. Also, while the first few balloons lasted only a day or two in flight, two-thirds now stay airborne for over 100 days, with the record currently being 138 days of flight [15]. (At the end of its life, a balloon can be landed in a reclamation zone, where the electronics are retrieved and reused and the plastic envelope recycled [4].)

Many governments and companies have expressed interest in working with Project Loon; as of January 2014, 24 countries had asked for testing and/or deployment in their country, and 10 of 10 telecom companies approached had agreed to profit-sharing agreements.

**Critical Analysis**

It is clear that Project Loon has had many successes in the last two years, both in proving the viability of its delivery system and by considerably improving its range and Internet speeds. Google now aims to “create a continuous, 50-mile-wide ring of Internet service around the globe” by the end of this year, and begin offering commercial cellular LTE service by 2016 [14]. (Its current monetization plan is to partner with local telecom countries, allowing them to use Loon to expand their existing mobile network in exchange for unspecified revenue sharing [4].)

But, while the vast majority of press around Project Loon is uncritically positive, there are still open questions left about the project’s potential. Even Project Loon's project manager is circumspect enough to say recently, “We’ve definitely crossed the point where there’s a greater than 50 percent chance that this will happen” (qtd. in [16]).

These open questions and concerns fall into four broad categories: (1) technical problems inherent in High-Altitude Platforms, (2) technical problems specific to the use of helium balloons, (3) logistical issues involving Google’s relationships with other partners, and (4) the question of whether Project Loon effectively addresses the most pressing barriers to Internet access in developing countries.

**Technical Problems of High-Altitude Platforms**

In 2006, Widiawan and Tafazolli [9] enumerated a large number of open research issues in the field of High-Altitude Platforms. Some of these have been solved in the intervening years, but others still constrain HAP systems.

The first of these open issues was rain attenuation and atmospheric loss. It is perhaps notable that Google has been running their field tests in the winter, when rain is least common in test sites such as the south island of New Zealand. However, rain attenuation is most significant above 10 GHz, while Google has been experimenting with lower frequencies—2.4 and 5.8 GHz in their initial tests, and undisclosed LTE bands (<1 GHz) in more recent tests. This is thus likely not an issue for Project Loon.

Second and third, finding a universally available frequency and dealing with interference are clearly ongoing concerns for HAP enterprises. Google began by using ISM radio bands because they are unregulated in every country—despite the fact that these bands are not designated for telecommunications use. Switching to LTE bands has simplified some parts of the system’s design (for example, the need for special receivers on cellular phones) but also means that Google will have to partner with telecoms in each relevant country to legally use this range.

Finally, handover and handoff are even more relevant to Project Loon than to most HAP systems, since a device on the ground will need to switch frequently to a new balloon. While Google has publicized the fact that people on the ground have successfully connected to their balloon-based network, to my knowledge they have not released data about how long those connections were sustained. It is therefore unknown at this point whether handoff from one balloon to another will be as simple as switching between cell towers or more difficult to achieve.

Generally, however, Google’s tests do give reason to believe that they have a handle on the most fundamental technical challenges of operating a High-Altitude Platform.
Balloon-Specific Problems

A number of technical challenges arise for Project Loon, not because it is a HAP but specifically because it is a balloon-based system. Indeed, most skeptics have focused their concerns on this area. In September 2013, hot air balloonist and aeronautical engineer Per Lindstrand went so far as to say that Google would be unable to keep a helium balloon afloat for more than three days—a rather strange claim, given that Google was already claiming 100+ day journeys at that time [13]

The question of steering balloons using stratospheric winds is a tricky one, though. Google has admitted that their tests flights have been around the same latitude because winds there are favorable; the successes it has had steering balloons around New Zealand and South America may not be repeatable closer to the equator. Lindstrand’s other persistent claim about the futility of using balloons as a High-Altitude Platform is that balloons inevitably end up at either the North Pole or the South Pole; they can’t be kept in a predetermined latitude indefinitely.

However, Google is not planning to launch balloons indefinitely. It plans to keep each envelope up for a few months at a time before landing it, recycling the balloon, and sending the payload back up on a new balloon.

Others have questioned the number of balloons needed, which could number in the millions; Google’s counterargument is that only a few tens of thousands are needed as long as they are steerable. They currently only have the infrastructure to keep about 2000 aloft at a time, but that infrastructure will presumably grow in the next few years.

A more serious concern is Google’s reliance for helium for this platform. In 2013 the world faced a significant helium shortage, with prices soaring to double what they had been a few years earlier. Some experts expect there to be cyclical helium shortages in the foreseeable future [17], which would make a helium balloon–based HAP untenable. However, Google has an answer for this, too: it is researching ways to use hydrogen balloons in a safer way than the famed Hindenburg did [4]. Whether it will find a way to make this transition is, however, yet to be seen.

A final concern about Google basing its Internet universalization plan on balloons is simply that other technologies may ultimately prove more tractable. Project Loon will probably be competing with Facebook/Internet.org’s drone-based HAP, as well as expanding satellite-based Internet from O3b, among other planned ventures. Google doesn’t seem very threatened by alternate technologies, though; it is investing heavily in O3b, and has even acquired two competing technologies itself — a satellite system called Skybox Imaging, and an unpiloted drone called Titan [18].

Logistical Issues

More mundanely, there are a number of logistics Google will need to work out to bring Project Loon online. Because the balloons will fly over many governments’ airspace, Google will need to secure flyover rights from each country at a given latitude in order to service countries in that latitude. If a single country refuses to grant flyover rights or work with it to build base stations, that country would effectively veto many other countries’ access to Project Loon. When asked about this, project manager Cassidy said only that such negotiations were going better than one might expect, and that many countries—even ones known for Internet censorship—were very welcoming of Project Loon [4]. However, it seems entirely unrealistic to expect that every country on Earth will be eager to partner with Google.

Google has solved radio frequency rights, another common concern, by partnering with local telecoms. However, this in itself raises other logistical issues. Will Google provide censored Internet connections in countries where the government requires telecoms to restrict Internet access? How will it deal with corrupt telecom systems? This may prove to be a thorny issue as Project Loon rolls out.

Does Project Loon Address the Right Issues?

A final critique of Project Loon is that providing expanded LTE coverage may not be the best approach to ensuring universal Internet access. Project Loon addresses two of McKinsey & Company’s four major barriers to Internet access: infrastructure and affordability. By providing Internet using cheaper infrastructure than terrestrial platforms, Loon promises to make the Internet available in locations that currently lack it, as well as in locations where it is currently too expensive for many consumers. However,
it does nothing to increase electrical infrastructure, which as a significant barrier to Internet in much of Africa. The high costs of charging a device in the absence of grid electricity will probably keep many low-income Africans offline even if Internet access itself becomes much more ubiquitous and affordable. And, of course, consumers will need to buy Internet-capable devices, which are still out of reach of those who live on a dollar a day.

Providing expanded LTE coverage also does nothing to ameliorate the other two problems, namely incentives and user capability. The 28 percent of offline individuals who are illiterate will be no more able to read a web page after getting Loon access than they are now. As Zuckerberg says, non-terrestrial network platforms

“will eventually be necessary to connect everyone since some people live in remote areas where there is just no infrastructure to connect them. But this isn’t the problem most people have. In fact, almost 90% of the world’s population already lives within range of an existing cellular network. For everyone in those areas, we don’t need to build completely new kinds of infrastructure to help them connect. We just need to show why it’s valuable and make it affordable” [5].

However, while Zuckerberg is right that 90% of people live in cellular range, we have already shown that Ericsson’s statistics support the idea that insufficient cellular network speed is a significant impediment to Internet access for 1.2 to 2.8 billion people. Upgrading service to 4G speeds for those people would be no small feat.

Conclusions

Project Loon is no panacea. No number of helium-filled balloons will solve every problem that prevents people, particularly those in developing countries, from participating fully in the Internet. However, implementing a large-scale High-Altitude Platform in rural, remote and underdeveloped areas will go a long way toward bringing the Internet to the 4.4 billion people who currently lack access. Together with other infrastructure improvements and improvements to educational systems in countries with low literacy, a project like Project Loon could make a significant impact on closing the digital divide. And, in fact, a well-implemented HAP could make those other changes more likely, both by increasing demand for the services needed to make available Internet useful, and by simplifying the logistics of planning and implementing government services in areas that previously lacked lines of communication.

In an article critical of both Project Loon and Internet.org, Newsweek technology columnist Kevin Maney opined,

“If past is any prologue, before a sky-based system can get deployed, it gets rendered obsolete and too expensive, and networks on terra firma expand enough to take a chunk of the customers the sky system had been counting on serving. At some point, the sky project faces reality and tells its rocket scientists to pack it in” [19].

Maney is correct that none of the world’s many HAP efforts have yet come to fruition. That clearly provides ample reason to be skeptical of Project Loon. However, in the last two years, Google has provided many reasons to be optimistic, too. Google has already had significant successes in improving the speed of Internet access balloons can provide, the geographical range a balloon can reach, and the lifespan of any given balloon. There is therefore reason to think that Project Loon may well succeed where others have failed, potentially expanding online access to many of the 4.4 billion people who currently lack any access to the Internet.
References


