Flying Internet for the Unwired: How to implement sky-streaming internet in the developing world

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Abstract

This study examines the implementation of innovative internet technologies in developing countries. Sky-streaming internet, which includes balloon internet from Google, drone internet from Facebook, and low-earth orbiting satellite internet from OneWeb aims to remove the digital divide by beaming the internet down to the most unwired regions in developing countries. This study first provides the concept, technical features, and major service providers of the three types of sky-streaming internet as an ICT4D initiatives to solve digital divide in developing countries. To seek practical implications for developing countries and sky-streaming internet service providers, this study proposes four research questions regarding its expected contributions, challenges, specific strategies, and comparison between the three technologies. The analysis integrates two different methods and data sources that include interviews with ICT4D experts on the first level, and an analytic hierarchy process analysis on the second level. Findings contribute to identifying the most critical challenges the sky-streaming internet service providers face and crucial issues to consider from the perspective of developing countries. Among the three sky-streaming technologies, the results of this study suggest that Google’s balloon internet is the strongest and most recommended option as it is the most realistic sky-streaming technology to be accepted from the authorities and local players in developing countries.

Keywords
Sky-streaming internet, ICT4D, balloon internet, drone internet, low-earth satellite orbiting internet, AHP

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1. Introduction

Connectivity is now almost a necessity for many people throughout the world. The internet has become an essential medium not only for communication, business, education, but also for many more functions of our daily lives (Calandrelli, 2015). On the other hand, fifty-four percent of the world’s 7.4 billion population still do not have access to basic internet service (BroadbandCommission, 2016). Likewise, almost half of the world is currently offline and the situation is more extreme in the developing world.

From the perspective of telecommunication operators, however, rural communities in developing countries are too costly and impractical business market to invest. These are the markets that do not promise return on investments. Despite the great impact connectivity and internet can bring, building network infrastructures for those people in bottom of the pyramid is unlikely an option for traditional telecommunication companies.

Several global IT companies like Google or Facebook have found ways in sky: flying internet from the sky using the most revolutionary forms of technologies. Google is floating balloons and Facebook is flying drones. OneWeb, a satellite startup, found a way in low-earth orbit. They claim that this innovation will extend internet connectivity to the most remote regions around the world that are suffering from digital darkness.

This study aims to provide practical business and policy implications for the three different types of sky-streaming internet technologies: balloon internet from Google, drone internet from Facebook, and low-earth orbiting satellite internet from a group-backed venture OneWeb. This study will first elucidate the detailed technical features of the sky-streaming internet technologies, its characteristics, and the major players providing those technologies. In the following section, the study elaborates on the concept of digital divide and Information Communication Technology for Development (ICT4D) as the main theoretical concepts for this study. Then, it will be followed by two analyses using two different types of data: expert interviews and an analytic hierarchy process analysis. Lastly, overall discussion and implications are provided.

2. Sky-streaming internet: Definition, technical features, and service providers

Sky-streaming internet refers to innovative connectivity technologies that provide internet ‘from the sky’. The three most representative types of sky-streaming Internet technologies include 1) Balloon internet, 2) Drone internet, and 3) Low-earth orbiting satellite internet. The traditional way to provide telecommunications network requires a certain set of facilities including cell towers. However, constructing cell towers and other infrastructures requires a significant amount of initial investments so the telecommunication operators are unlikely to invest in regions with low demand of network and low return on investment. For this reason, 54% of the world’s 7.4 billion population still do not have access to basic internet services (BroadbandCommission, 2016). As a solution to this problem, several global IT firms have come up with innovative technologies to provide connectivity in those areas. The pioneering players are Google, Facebook, and a group-backed startup OneWeb.

2.1. Project Loon from Google – Balloon Internet

Project Loon is what Google suggests as one of the solutions for connecting the two-thirds of the world’s unwired population by flying balloons equipped with a transceiver (X.Company). Loon refers to a network of balloons travelling on the very edge of space as an effort to close the digital gap worldwide. The basic idea is to use a fleet of gas-filled balloons hovering in the sky around the world at the height of
20-30 km up in the stratosphere, well above airplanes and weather events (<Figure 1>). According to Google, their balloons are equipped with the most essential components of a cell tower and are powered entirely by its solar panels. One balloon can beam down internet to an area of 80 km in diameter using LTE technology at the speed of 22 MB/s. Google explains that by moving with the wind, the balloons can be efficiently arranged to provide coverage to where it is needed (Kyle, 2016).

Although the balloon internet has weakness in its relatively fragile material, it has comparative advantage in manufacturing cost. In addition, the launching process and management is simpler than that of satellite or drone. Another noteworthy strength of Google’s Project Loon is its partnership-building experience with local telecommunications operators in many developing countries. Google is not interested in going alone but rather interested in serving as a supplementary network for wider internet and communication.

Project Loon has gone through multiple times of pilot tests in many areas including New Zealand, Brazil, Sri Lanka, Indonesia, Puerto Rico, Canada, Peru, and India. Google is in progress and in talk with the government officers and local mobile operators to officially launch Project Loon service in those countries.

Source: Alphabet X webpage

<Figure 1> Google’s Project Loon

2.2. Aquila from Facebook – Drone Internet

Facebook has been running the ‘Connectivity Lab’ with an aim to develop ways to make affordable internet access possible in underserved communities around the world. As one of the projects at the Connectivity Lab, Facebook invested in its drone technology beaming down the internet through lasers to create Wi-Fi or 4G network, named ‘Aquila’ in June 2015 (Hern, 2015).

Aquila, meaning eagle in Latin, refers to the unmanned aircraft that beams down the internet from the sky. Aquila has the 42 m (137 ft) wingspan, the same size with Boeing 737, but only weighs around 400 kg as it was made with a special carbon-fiber frame material (<Figure 2>). The drone will operate between 60,000 ft (18 km) and 90,000 ft (27 km), delivering high-speed internet connectivity to a 96.5-kilometer-diameter region. It is solar-powered and able to fly without landing for three months at a time (Hern, 2015; Vizocom, 2016). Aquila uses laser beams to deliver internet instead of radio spectrum, shooting signals embedded in light. Facebook’s plan is to deliver 10 MB/s to a target that is the size of a dime from over 10 miles away. As small towers on the ground receive the signals from the drone, the signals will be converted to a Wi-Fi or LTE network. The goal is to have multiple drones connected to each other to create a larger network and deliver more coverage (TheInternetExperts).

Aquila has completed the first pilot flight last year in Arizona, US (Facebook, 2016). Facebook announced that it will keep testing Aquila in the upcoming years but no specific plans are not officially announced. Facebook also seeks to create partnership with the existing telecom operators instead of providing internet service by itself.
2.3. Low-earth orbiting (LEO) satellite internet by OneWeb

The most conventional and common way of providing mobile internet is cellular. Cellular communication is a ground-based network communication that are created with physical cables. However, there exist many situations where building infrastructure and transmitter towers are unlikely. Telecom operators do not have motivation to invest and build necessary infrastructure in low density communities where the cost per user is too high (Calandrelli, 2015). In these cases, satellite communication often emerges as an answer.

Satellite internet signals are transmitted far above the earth and do not rely on towers built on land, making them particularly very useful in remote, wild areas. Companies like OneWeb devised an idea of giving internet connectivity from the Low-Earth Orbiting (LEO) satellite. OneWeb, founded by Greg Wyler, is a US satellite startup backed by SoftBank Group, Qualcomm, and many other giant companies is working on developing micro-sized satellites, which will operate in circular low-Earth orbit.

OneWeb will put the total 2,620 micro-sized constellations in the low-earth orbit at 1,200km in altitude (Pultarova, 2017). The average cost to manufacture a conventional satellite is $250 million whereas the micro-satellite suggested by OneWeb will cost only $500 thousand, only 1/500 of the conventional one. As for the size and weight, a low-earth orbiting satellite weighs around 110kg (250lb) and a size of a washing machine (<Figure 3>). The satellite designed by OneWeb is expected to provide internet at the download speed of 200Mbps. It also is compatible with existing communication standards including 2G, 3G, LTE, and Wi-Fi.

OneWeb has a mission to cover the Earth with a blanket of micro-satellites in low-earth orbit to provide internet connectivity at every school in the world by the year of 2022 and to fully bridge the digital divide by 2027, making internet access available and affordable for everyone. OneWeb plans to launch its initial ten production satellites in early 2018. For mass production of the satellites, OneWeb has just begun constructing the satellite factory in Florida, which will be finished around 2020.
<Table 1> below briefly summarizes the technical features of the three different types of sky-streaming technologies elaborated above. In the next section, the key theoretical concepts that can explain the adoption of sky-streaming internet technology in developing countries will be presented.

<Table 1> Three different types of sky-streaming internet technology

<table>
<thead>
<tr>
<th>Project Loon</th>
<th>Facebook Aquila</th>
<th>OneWeb Low-earth orbiting Internet</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flight height</td>
<td>20-30km in the stratosphere</td>
<td>18-27km in the stratosphere</td>
</tr>
<tr>
<td>Lifespan</td>
<td>Maximum 190 days</td>
<td>Approximately three months (90 days)</td>
</tr>
<tr>
<td>Network coverage</td>
<td>80km in diameter</td>
<td>96.5km in diameter</td>
</tr>
<tr>
<td>Internet speed</td>
<td>22 M/8/s (expected)</td>
<td>10 M/8/s (expected)</td>
</tr>
<tr>
<td>Test flights</td>
<td>Multiple pilot tests done in eight countries</td>
<td>A pilot test done in the US</td>
</tr>
<tr>
<td>Strength</td>
<td>relatively low-cost, high feasibility based on</td>
<td>Reusing down laser</td>
</tr>
<tr>
<td></td>
<td>multiple pilot tests</td>
<td>transmit data</td>
</tr>
<tr>
<td>Weakness</td>
<td>Low durability of the balloon</td>
<td>Issues with Free Basics in some developing countries</td>
</tr>
</tbody>
</table>

3. Theoretical concepts: digital divide and ICT4D

3.1. Digital divide

Digital divide, a term first used by Larry Irving, originates from the divisive aspect of information and communication technologies (ICTs) (Cheruiyot, 2011). It refers to the gap between ICT haves and have-nots, which can be individuals, households, businesses, or geographic areas at different socioeconomic levels with regards to both access and use of ICTs for a variety of activities (Hsieh, Rai, & Keil, 2008; Katz & Aspden, 1997; Norris, 2001; OECD, 2001; World Bank, 2006). International Telecommunications Union (ITU) also referred to the concept of digital divide as the existing gulf between those who benefit from digital technologies and those who do not (ITU, 2007).

Applying digital divide on the citizens’ level, the digital divide means a gap among citizens in a society who are advantaged or disadvantaged by ICTs (Rogers, 2001; Sukkar, 2004). Rogers emphasized how digital divide emerges from the lack of telephones, computers, broadband internet, and many other information technologies and how they are closely connected to an individual’s socio-economic characteristics (Rogers, 2001). DiMaggio, Hargittai, Neuman, and Robinson (2001), on the other hand, rather coined this concept with a stronger focus on the internet connectivity by explaining digital divide as “inequalities in access to the internet, extent of use, knowledge of search strategies, quality of technical connections and social support, ability to evaluate the quality of information, and diversity of users.”.

Since the early 2000s, digital divide and the similar concepts like digital exclusion or digital inequalities have been actively investigated in academia ranging from media, communication and telecommunications (Helsper, 2012; Howard, Busch, & Sheets, 2010), sociology (Blank & Groselj, 2015; DiMaggio et al., 2001; Hassani, 2006; Khatiwada & Pigg, 2010) and public policy (Mir & Dangerfield, 2013; Philip, Cottrill, Farrington, Williams, & Ashmore, 2017; Pick & Nishida, 2015; Servon, 2008; Skerratt, 2010). One important point raised by some of the existing literatures is that one of the major
factors behind the digital divide’s persistence is unequal investment in telecommunications infrastructure (Philip et al., 2017; Rogers, 2001; Servon, 2008). Rogers explained that today’s most common and direct cause of digital connectivity lies on the lack of network infrastructure, which can be termed as ‘Internet access-divide’ (Rogers, 2001). As the ICT technologies keep being innovated and the products are being mass-produced, the price for the devices including cell phones and personal computers have continuously dropped. This made the people even in the most marginalized regions of the world access and own an ICT device. Nevertheless, connectivity problem remains. Thus, the real hurdle of digital divide is now internet connectivity, not the device access point, in remote areas of developing countries (Mariscal, 2005; Rao, 2005; Suwarwoto & Tampubolon, 2016).

3.2. ICT4D and Sky-streaming internet

‘ICT4D’, an abbreviation for Information Communication Technology for Development can be briefly defined as the application of information and communication technologies for the purpose of helping poor and the marginalized people to make a positive difference to their lives (Heeks, 2009; Unwin, 2009). ICT4D focuses on how the ICTs can contribute to the ‘development’ and ‘empowerment’ in the developing countries that suffer from marginalization (Unwin, 2009).

Robert Atkinson, the president of the Information Technology for Innovation Foundation, has once said that internet penetration is positively correlated and closely related to increases in exports (Dews, 2014). In fact, it was found that a 10 percent increase in internet penetration is associated with a 1.7 percent increase in exports.

Many statistics and researches emphasize the positive impact the internet - mobile internet in particular - can bring into the developing world (Ghosh, 2016). For instance, a rise in 10% of the population owning a mobile may lead to an increase in GDP growth of 0.5%, according to a study (Worstall, 2014). Along with the economic growth, internet connectivity also fosters innovation in the developing world. Paunov and Rollo (2016) revealed that industries’ use of internet positively affects the firm’s productivity quality certificates and patents in developing countries. Aside from these, it has been repeatedly pointed that the internet helps the entire society grow in terms of education, politics, healthcare, and many others (Chou & Fu, 2016; Hoque, 2016).

Despite such merits of the internet, domestic telecom operators of the developing countries have little incentives and capacity to build network infrastructures largely due to low return on investment. Global IT firms and financially stable ventures have come up with an innovative solution to this: Sky-streaming internet technologies. Google is working on its balloon internet, Project Loon, and Facebook is testing drones to beam down the internet from sky. A group-backed startup OneWeb chose low-earth orbiting satellite technology for universal internet connectivity.

The purpose of this study has three pillars: First, this study aims to provide a comprehensive guide and evaluation of three types of sky-streaming internet technologies to the national policymakers looking for ways to extend connectivity in their countries. No academic paper has yet properly organized and analyzed such kinds of innovative technologies that can serve as an alternative solution for regions in digital darkness. Then, the second pillar of this study’s purpose is to give practical implications to sky-streaming internet service providers including Google, Facebook, and OneWeb. What challenges should the sky-streaming internet service providers overcome? What kinds of factors should be concerned in specific strategies to make their projects happen in developing countries? Answers for these questions will be sought in this study. Lastly, this study also hopes to make an academic contribution as one of the most pioneering, exploratory research regarding a state-of-the-art communication technology for ICT4D. Most of the ICT4D studies tend to focus more on ‘development’ but this research puts heavier weight on the technology side of ICT4D and then investigates how this innovative technology can contribute to a nation’s development.
In this light, this study investigates the following four research questions.

RQ1. Will the sky-streaming internet technology positively contribute to the development of developing countries? If so, how? If not, why?

RQ2. For sky-streaming internet technologies to be deployed in developing countries, what are the most critical challenges to overcome?

RQ3. What should be done and how should it be done by whom to make a sky-streaming technology be successfully deployed and to extend internet connectivity to developing country?

RQ4. What criteria or factors should the developing countries consider when selecting and deploying a sky-streaming internet technology?

4. Research method

This study attempts to find answers to the proposed research questions by two-level analysis: interview with ICT4D experts on the first level, and an analytic hierarchy process (AHP) analysis on the second level.

4.1. Interview with ICT4D experts

The study first interviewed ICT4D experts for sky-streaming internet adoption idea in developing countries. Interviews were conducted with the participants at an international ICT4D conference held in Hyderabad, India from May 15th to 18th, 2017. Total of eleven experts from non-governmental organizations, private sector, association, research institution, or an independent consulting firm participated in the interview for this study. Their career fields were divergent ranging from connectivity, healthcare, agriculture, urban planning, water and sanitation, education, to ICT4D in general as an academic field(<Table 2>).

<table>
<thead>
<tr>
<th>Organization</th>
<th>Number</th>
<th>Expertise</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-governmental / Civic organization</td>
<td>6</td>
<td>Network / Connectivity</td>
<td>3</td>
</tr>
<tr>
<td>Corporate</td>
<td>2</td>
<td>ICT4D in general</td>
<td>3</td>
</tr>
<tr>
<td>Consulting firm</td>
<td>1</td>
<td>Healthcare / Agriculture</td>
<td>2</td>
</tr>
<tr>
<td>Association</td>
<td>1</td>
<td>Urban planning / Housing</td>
<td>1</td>
</tr>
<tr>
<td>Research institution</td>
<td>1</td>
<td>Water / Sanitation</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Education</td>
<td>1</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>11</strong></td>
<td><strong>Total</strong></td>
<td><strong>11</strong></td>
</tr>
</tbody>
</table>

4.2. Analytic Hierarchy Process (AHP) analysis

On the second level, this study has also conducted an analytic hierarchy process (AHP) analysis to suggest a model that can help developing countries select a sky-streaming internet service. As for the sky-streaming internet service providers, the result from this AHP analysis can be used as a valuable ground
in devising business strategies. An analytic hierarchy process (AHP) model is a widely used theoretical modeling technique for complex decision making process (Saaty, 1990) and has been widely adopted by a great number of social scientists in areas of policy, communications, business, etc. (Chen & Wang, 2010; Huang, Chu, & Chiang, 2008; Kim & Kim, 2016; Neokosmidis et al., 2017).

There are three major factors or criteria that potentially affect the adoption of an innovation or technology: technology, government, and market. The Technology-business-policy (TBP) or Technology-business-government framework is a traditional analysis tool that have been adopted in the studies analyzing the value of telecommunications systems (Esmailzadeh, 2016; Neokosmidis et al., 2017) and a new innovative technology (Kim & Kim, 2016; Park, Kim, & Nam, 2015).

The first main criterion, technological superiority, can be more specifically explained by sub-criteria: technical viability, cost-effectiveness, network coverage, and the technical performance. The second criterion is socio-political acceptance and it can be divided into three sub-criteria: acceptance from the authority, local players’ cooperation, and social acceptance. Lastly, the third criterion is market potential. Market potential criterion consists of three sub-criteria: profitability, sustainability, and the impact of the sky-streaming technology on the economic growth (<Figure 4>).

4.2.1. Technological superiority criterion

Drone, balloon, and low-earth orbiting satellite internet technologies are the newest and the most innovative alternative telecommunication technologies for connectivity. One important aspect of an ICT innovation is its technical excellence. To examine the technical superiority of a sky-streaming internet technology, we can evaluate the technology by the following four sub-criteria (<Table 3>).

<table>
<thead>
<tr>
<th>Sub-criteria</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technical viability</td>
<td>Is this sky-streaming internet technology technically viable and feasible enough?</td>
</tr>
<tr>
<td>Cost-effectiveness</td>
<td>Is this sky-streaming internet technology cost-effective in terms of construction, operation, and management?</td>
</tr>
<tr>
<td>Network coverage</td>
<td>Does this sky-streaming internet technology provide wide network coverage in developing countries?</td>
</tr>
<tr>
<td>Technical support</td>
<td>Does this sky-streaming internet technology support</td>
</tr>
</tbody>
</table>
4.2.2. Socio-political acceptance criterion

Despite technical excellence, an innovation or technology cannot successfully operate unless the government and the society accepts it. When the innovation is from a foreign power, the socio-political acceptance is even more challenging yet important (Simonite, 2016). A sky-streaming internet technology must gain a permit and support from the government for its spectrum usage, installation and operation of their flying tools in their territory. Local market players like mobile operators or device makers must be cooperative to this new, foreign technology. Also, the acceptance from the people is essential. Thus, this study puts the following three sub-criteria under the socio-political acceptance criterion (<Table 4>).

<table>
<thead>
<tr>
<th>Sub-criteria</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acceptance from the authority</td>
<td>Will the government of developing countries permit and support the adoption of this sky-streaming internet technology?</td>
</tr>
<tr>
<td>Local players’ cooperation</td>
<td>Will the local market players like mobile operators, device makers, and content providers be cooperating with this sky-streaming internet technology?</td>
</tr>
<tr>
<td>Social acceptance</td>
<td>Will the people, internet service users, or civic groups accept this sky-streaming internet technology and not show resistance to the technology?</td>
</tr>
</tbody>
</table>

4.2.3. Market potential criterion

Even if an innovation is technologically excellent and accepted by the government and society, it must have business value to actually work in the market. Market potential of a sky-streaming internet technology can be examined by its profitability, sustainability, and positive impact on the developing country’s economic growth (<Table 5>).

<table>
<thead>
<tr>
<th>Sub-criteria</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Profitability</td>
<td>Does the adoption of this sky-streaming internet technology in developing countries positively contribute to the company’s profitability?</td>
</tr>
<tr>
<td>Sustainability</td>
<td>Does this sky-streaming internet technology have sustainable business in developing countries? (ex. creation of ecosystem, favorable relationship-building with local players, etc.)</td>
</tr>
<tr>
<td>Impact on economic growth</td>
<td>Will the adoption of this sky-streaming internet technology bring about positive impact on the developing country’s economic growth? (ex. industrial growth in telecommunications sector, growth in other industrial sectors like commerce, banking, agriculture, etc.)</td>
</tr>
</tbody>
</table>

5. Result

5.1. Interview with ICT4D experts

Interviews with the eleven ICT4D experts have covered diverse aspects of sky-streaming internet
technologies for developing countries. Based on the integrated analysis of the interviews, the result can be provided on two levels: 1) Meaning and expected impact of the sky-streaming internet technology adopted in developing countries, and 2) Strategic considerations of sky-streaming internet technology from the perspective of the beneficiary, which refers to developing countries, and the service providers, which refers to Google, Facebook, and OneWeb.

5.1.1. Meaning and expected impact of the sky-streaming internet technology in developing countries

The three sky-streaming internet service providers – Google, Facebook, and OneWeb – are allegedly working on this innovation project to make the world a better place. However, many of the interviewees were rather skeptical, pointing out their long-term plan of expanding potential market. An ICT4D researcher from the interview doubted the “real deal behind the altruistic actions”.

The technical viability of sky-streaming internet was also questioned by the experts. The potential impact the sky-streaming internet can bring was mostly agreed but the most important part lies on the readiness of technology, particularly for OneWeb’s low-earth orbiting satellite internet. Another important point suggested by the interviewees regards with the existence of a more “realistic, proven, and even lower-cost” technologies for internet. There might be other technologies for internet connectivity in developing countries and they seem to be more realistic and economical. For instance, mesh network technology, OpenBTS, TV white space, or other innovative technologies that use small cells may look more tempting from the perspective of developing countries.

In general, the positive impact of internet and mobile penetration on a country’s economic growth have been repeatedly emphasized by the interviewees. The repercussion from the internet connectivity, if it is properly given, can be found in many parts of the society. All areas of ICT4D that range from agriculture, environment, education, healthcare, banking and commerce, to disaster management will be improved. Access to information using the internet will also bring about constructive changes in social and political parts of the society. Access to information is a “critical driver of social and political changes” and improved communications and information have been a “pre-condition for even peace and reconciliation.

5.1.2. Strategic considerations of sky-streaming internet technology from the perspective of the beneficiary and the service providers

There exist many critical diplomatic and political issues within sky-streaming internet technologies from the perspective of the developing country’s authorities and then can be summarized in three: spectrum, internet governance, and national security issues. That is, sky-streaming internet is not free from the concerns of spectrum interruption with local operators, protection of internet governance and national security of developing countries. The interviewees pointed that the government and ministries should have enough conversations with the internet service providers to ensure their long-term plans that include how these technologies will be withdrawn in the future without hurting the society, whether the technology is going to be transferred to the developing country and if not whether the service providers are willing to help build a sustainable internet infrastructure in the country, how and to what degree the internet service providers will hire and train people on the ground, etc. Also, as reflected in the case of Facebook’s Free basics program banned in India, the acceptance from the society and the people is crucial. Facebook’s Free Basics is a zero-rating data plan provided by Facebook partnering with a local network operator. It started off well in India but the net neutrality issue raised by local civic groups made the program removed in the country.

As for the sky-streaming internet service providers, some of the interviewees particularly the ones with first-hand experience in ICT4D business emphasized the importance of putting investments in the business and social side much earlier to be prepared for the market. In fact, Baldwin and Thomas (2005) noted that many ICT4D projects has failed because they have tended to concentrate first on the
technologies and only later have they addressed the potential that those technologies can offer to the people in developing countries. Sky-streaming internet service providers should put the permission from the government on the priority. Innovation technologically possible is not enough (H. Dutton, 2014). The challenge is to make the innovation actually happen in the society and the first hurdle is to get permission and supports from various national governments of the country. Another important strategic consideration for the internet service providers is to build a network with diverse stakeholders – not only the local mobile operators, but also so many NGOs that work on extending connectivity and companies that need better internet connectivity. They should start building a network with ventures, NGOs, and other companies working for the similar mission in the area.

5.2. Analytic Hierarchy Process (AHP) analysis

An AHP analysis was conducted to propose a model that can help developing countries when selecting a sky-streaming internet service provider. The total of twenty-five experts participated but this study analyzed twenty-two cases that show CR below 2.0 (<Table 6>). About 48% (12 out of 25) of the respondents were from the international community and the rest 52% (13 out of 25) were from South Korea.

<table>
<thead>
<tr>
<th>Affiliation</th>
<th>CR &lt; 0.1</th>
<th>CR &lt; 0.2</th>
<th>Unfiltered</th>
</tr>
</thead>
<tbody>
<tr>
<td>Private Sector Business</td>
<td>7</td>
<td>11</td>
<td>11</td>
</tr>
<tr>
<td>University / Educational Institution</td>
<td>4</td>
<td>4</td>
<td>7</td>
</tr>
<tr>
<td>Research Institute</td>
<td>2</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>NGO / Civic Organization</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Policy / Government Relations</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Foundation / Association</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>16</strong></td>
<td><strong>22</strong></td>
<td><strong>25</strong></td>
</tr>
</tbody>
</table>

5.2.1. Criteria weights

The results showed that socio-political acceptance (0.434) was found to be the most crucial criterion over the other two, market potential (.313) and technical superiority (.253) criteria in the first layer of the model. In terms of sub-criteria under socio-political acceptance factor, the local score of acceptance from the authority criteria was the highest (.516) followed by local players’ cooperation (.307) and social acceptance (.177) (<Table 7>).

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Weight ($W_C$)</th>
<th>Sub-criteria</th>
<th>Local score ($W_L$)</th>
<th>Global weight ($W_C*W_L$)</th>
<th>Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technical superiority</td>
<td>.253</td>
<td>Technical viability</td>
<td>.302</td>
<td>.076</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cost-effectiveness</td>
<td>.351</td>
<td>.089</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Network coverage</td>
<td>.221</td>
<td>.056</td>
<td>9</td>
</tr>
</tbody>
</table>
As for the second important criteria, market potential, the sub-criteria sustainability showed the highest local score (.402) and then impact on the economic growth in the developing countries (.395), and profitability (.203) followed. The least important criteria, technical superiority consists of four sub-criteria. Among the four, cost-effectiveness of the sky-streaming internet technology was evaluated as the most important (.351) followed by technical viability (.302), network coverage (.221), and lastly technical performance (.127).

The global weights refer to the ultimate relative importance of each factor placed in the lower layer of the AHP criteria, which indicate the products of all the weights in linear association. These weights of ten sub-criteria were calculated by multiplying the upper-level criteria weight and the local score. It was revealed that the most important criterion in evaluating sky-streaming internet technologies for developing countries is the authority’s acceptance (.224). The second important criterion is also under socio-political acceptance umbrella as local players’ cooperation (.133). The third and fourth important criteria were in market potential criteria as sustainability (.126) and impact on economic growth (.123). The difference between these two were very marginal whereas the gap between the first (.224) and second (.133) was relatively distinct. Then, it was followed by cost-effectiveness of the technology (.089), the society and user's acceptance to the technology as a service (.077), and the viability of technology (.076). The gap between the 6th and 7th was quite minimal as .001. so it can be explained that the importance of technical viability is almost tantamount to that of social acceptance. Profitability (.063), network coverage (.056), and technical performance (.032) were the three least important factors to be considered in developing countries’ adoption of sky-streaming internet technology.

5.2.2. Alternative priority
The priority of the three alternatives can be computed by multiplying the products of each criteria weight($W_c$) and the three alternatives’ local score weight($W_l$) for the ten sub-criteria included in the model. The sum of all the global weights will make the total weight of each alternative due to criteria weight ($\Sigma$ $W_c$ * $W_l$). The results of the local scores for each of the three alternatives, Google's balloon internet, Facebooks' drone internet, and OneWeb's low-earth orbiting satellite internet are demonstrated in Appendix 1.

The results show that Google's balloon internet holds advantages in its potential capability of partnership with local players (.501) and the viability of the balloon technology (.483). Google's balloon internet was also evaluated as a strong candidate as the most feasible technology to be permitted by the government ministries of developing countries (.474). On the other hand, however, the balloon internet was not perceived as a sustainable (.272), high-quality (.253), wide-coverage (.198) network.

Meanwhile, low-earth orbiting satellite internet provided by OneWeb had advantages in what Google's balloon internet was weak at. OneWeb's satellite internet is a strong candidate that can provide

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Sub-criteria</th>
<th>Technical performance</th>
<th>Acceptance from the authority</th>
<th>Local players’ cooperation</th>
<th>Social acceptance</th>
<th>Profitability</th>
<th>Sustainability</th>
<th>Impact on economic growth</th>
</tr>
</thead>
<tbody>
<tr>
<td>Socio-political acceptance</td>
<td>.434</td>
<td>.127</td>
<td>.516</td>
<td>.307</td>
<td>.177</td>
<td>.203</td>
<td>.402</td>
<td>.395</td>
</tr>
<tr>
<td>Market potential</td>
<td>.313</td>
<td>.032</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
fast and stable internet (.455) to a wide range of area (.608) sustainably (.440). As opposed to Google’s Loon, OneWeb’s low-earth satellite internet may face serious challenges in obtaining the partnership and cooperation from the local market players (.220) or the government (.242). Also, another challenge for the low-earth orbiting satellite internet lies on its ‘too futuristic’ technology which indicates a low technical viability (.223).

Drone internet from Facebook seems to be somewhere in the middle of the other two. Facebook’s drone internet, however, was distinguishable in that it showed high score in cost-effectiveness (.312), social acceptance (.3), and profitability (.296). Thus, it is a good option for a sky-streaming internet provide that prioritizes making profits with smooth adoption to the society and users. Drone internet from Facebook showed low score in network coverage (.195), impact on economic growth in the developing country (.272), and local players’ cooperation (.279).

The total weights of the three alternatives, as shown in <Table 8>, indicate that the best sky-streaming internet technology option for developing countries is likely to be Google’s balloon internet(.394), followed by OneWeb’s low-earth orbiting satellite internet(.323), and Facebook’s drone internet(.283).

Looking specifically at the global weights by the criteria that were gained by multiplying criteria weights and local scores, all three sky-streaming internet technologies gained significant weights from the criterion of acceptance from the authority and the least weights from technical performance criterion. The AHP model with the weight scores is depicted in Appendix 2.

<Table 8> AHP alternatives’ priority due to criteria weights

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Criteria Weight ($W_c$)</th>
<th>Google's Project Loon (Balloon Internet)</th>
<th>Facebook's Aquila (Drone Internet)</th>
<th>OneWeb's Low-Earth Orbiting Satellite Internet</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Global Weight ($W_c * W_l$)</td>
<td>Rank</td>
<td>Global Weight ($W_c * W_l$)</td>
</tr>
<tr>
<td>Technical Superiority</td>
<td>TV .076</td>
<td>.037</td>
<td>4</td>
<td>.022</td>
</tr>
<tr>
<td></td>
<td>CE .089</td>
<td>.035</td>
<td>5</td>
<td>.028</td>
</tr>
<tr>
<td></td>
<td>NC .056</td>
<td>.011</td>
<td>9</td>
<td>.011</td>
</tr>
<tr>
<td></td>
<td>TP .032</td>
<td>.008</td>
<td>10</td>
<td>.009</td>
</tr>
<tr>
<td>Socio-political Acceptance</td>
<td>AA .224</td>
<td>.106</td>
<td>1</td>
<td>.064</td>
</tr>
<tr>
<td></td>
<td>LP .133</td>
<td>.067</td>
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<td>.037</td>
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<tr>
<td></td>
<td>SA .077</td>
<td>.032</td>
<td>7</td>
<td>.023</td>
</tr>
<tr>
<td>Market Potential</td>
<td>PR .063</td>
<td>.020</td>
<td>8</td>
<td>.019</td>
</tr>
<tr>
<td></td>
<td>ST .126</td>
<td>.034</td>
<td>6</td>
<td>.036</td>
</tr>
<tr>
<td></td>
<td>EG .123</td>
<td>.043</td>
<td>3</td>
<td>.034</td>
</tr>
<tr>
<td>Total Weight</td>
<td>$\sum([W_c * W_l])$</td>
<td>.394</td>
<td>.283</td>
<td>.323</td>
</tr>
<tr>
<td>Alternative Ranking</td>
<td>1</td>
<td>3</td>
<td>2</td>
<td></td>
</tr>
</tbody>
</table>

To summarize, the AHP analysis aimed to provide a model that can help developing countries’ decision-making concerning sky-streaming internet technology. Among the three criteria on the first layer
of the model, socio-political acceptance (0.434) showed the highest score and then followed by market potential and technical superiority. This indicates that the sky-streaming internet technology service providers should start putting efforts in the relationship-building with the government and the local market players in the targeted developing countries. The global weights of each sub-criterion show high importance of local players’ willingness to cooperate with the sky-streaming internet service provider and the sustainability of the technology. Both showing high scores as the second and the third most important may give an interesting implication. Stable relationship and close cooperation with local players, government ministries, working civic groups, other international organizations, and even the individual citizens in the region are the core factors for sustainable, successful ICT4D initiatives.

Also, the results indicated that the best sky-streaming internet technology option for developing countries is Google's balloon internet as it is a feasible, realistic technology that can be accepted by the government and local players of developing countries. These three criteria – technical viability, acceptance from the authority, and cooperation from the local players – were the most important criteria and the fact that Google showed strength in those three factors made it outweights in scores over the other two technologies. OneWeb, on the other hand, had what Google’s balloon internet did not have. OneWeb's low-earth orbiting satellite internet was evaluated as a technically superior with wide network coverage and sustainability. However, OneWeb was weak at forming partnership with local players and obtaining permission from the government. As for Facebook, its drone internet was evaluated as the weakest among the three with relative advantage on the factors of cost-effectiveness and social acceptance and profitability. The result implied that Facebook would be exceptionally well-accepted by the public compared to the other two sky-streaming internet services. Facebook’s familiar brand image as a global social network service may lower the psychological barrier to the internet service Facebook provides.

6. Conclusion and implication

This paper has presented four main research questions and the two analyses - one based on the interviews with eleven ICT4D experts and another one based on an AHP approach - provided answers to the questions.

The first question was answered by the expert interview analysis. This study attempted to confirm the positive impact of sky-streaming internet technologies on developing countries’ development by extending connectivity. The result indicated that although most of the experts agreed the positive impact of sky-streaming internet, the viability of technology should be further investigated. The first analysis also identified some of the most critical challenges Google, Facebook, and OneWeb face regarding their sky-streaming internet projects. The first hurdle comes from the government of developing countries. The sky-streaming internet service providers need to deal with the spectrum, internet governance, and national security issues residing in this innovative internet technology to make the developing countries’ government and regulation offices agree with them. The next hurdle lies on partnering with local telecom operators. The sky-streaming internet service operators are also in need of proposing an attractive business plan for the local players. The last challenge was found to be from the society and users. These challenges identified from the interview analysis were also well-reflected in the AHP analysis. As expected, socio-political acceptance factor particularly the acceptance from the authority and local players’ cooperation were found to be the most important factors to consider for a sky-streaming internet technology in developing countries.

This study has also provided strategic considerations regarding what factors should the sky-streaming internet service providers take into consideration when devising a strategy for developing countries. The key strategy inferred by the ICT4D experts interview can be summarized as 'building partnership to make a network'. The government is an important partner because it is the authority but
what is as crucial as the acceptance from the authority is to form a network with diverse stakeholders in developing countries. The stakeholders here include not only local mobile operators, vendors, and content creators but also other international NGOs or companies putting similar efforts in those regions.

The last research question, which sky-streaming internet service provider among Google with balloon internet, Facebook with drone internet, and OneWeb with low-earth satellite internet may be the best option for developing countries was mainly answered by the AHP analysis. The results implied that the most competitive candidate at this point is Google’s Project Loon. The second best option was found to be OneWeb’s low-earth satellite internet and the last was Facebook’s drone internet. Google was evaluated in the analysis as the most ‘realistic’ option for developing countries. It is the only sky-streaming internet service provider that have executed multiple times of pilot tests in many developing countries and thus the viability and readiness might have been considered relatively high.

On the other hand, OneWeb had strong comparative advantages in network coverage, technical performance, and profitability. That is, its low-earth orbiting satellite internet is seen as a technically superior with wide network coverage and sustainability. This comes from the unique technical characteristics of satellite internet in low-earth orbit. However, OneWeb is challenged with forming partnership with local players and obtaining permission from the government in developing countries. This implies that the experts view the low-earth orbiting satellite internet technology as ‘too far’ from now, and contains many features that can make developing countries concern and resist. The idea of floating satellites by an international company is in direct conflict with national security and the governance issue of the developing countries.

Facebook’s drone internet had advantage in cost-effectiveness and social acceptance. The result indicated that Facebook’s drone internet will be relatively well-accepted by the users thanks to Facebook’s brand power as a global social media leader. Also, Facebook has been running its Internet.org project under the official mission of ‘providing connectivity to the people unconnected’ and this may positively influence the social acceptance.

This study provided meaningful contributions to many parties. First and foremost, sky-streaming internet service providers can utilize the findings from this study for their business and marketing strategies in developing countries. The government officials and regulators of developing countries can consider the study results in devising national telecommunication industry blueprint. This study has also contributed to academia particularly in the fields of development, innovation, and telecommunication.

Nonetheless, this study is not without limitation. Although the three types of sky-streaming internet included in this study are the leading technologies, there could be concerns regarding other alternative technologies. The interviewees have mentioned that there exist other alternatives that are potentially more realistic and practical. Also, only a limited number of experts were interviewed and included in this study but there should be more experts included in further researches.

Furthermore, this study is based on assumption that the three technologies are only in competition. The possibility of two or more sky-streaming internet technologies implemented in one region and complementing each other were neglected. In a similar sense, how the sky-streaming internet service providers can supplement and cooperate with local mobile operators were not specifically covered in this study. A study about this topic can yield practical business implications for the stakeholders in telecommunication market of developing countries.

Moreover, the implementation of sky-streaming internet should also be examined by different research methods and data. The current research has contributed as a pioneering, exploratory research but was not able to provide specific strategies. Further studies should consider integrating data from potential internet service users in developing countries, interviews with managers and policymakers, etc.

Along with the application in developing countries, scholars may study the application and usage of sky-streaming internet in developed countries. For instance, these technologies can fill the blind spots of internet coverage such as mountain villages, marina sites, or desert areas. In addition, this technology can
serve as an emergency internet in times of disasters. In fact, Google recently gained FCC permission to launch its Loon service over U.S. Virgin Islands and Puerto Rico. Those regions are currently severely damaged by a hurricane and Loon will provide emergency connectivity cooperating with local telecom operators. Also, sky-streaming internet technology can make a business model for telecom or airline companies by providing in-flight internet services. Further studies should investigate the possibility, business strategies, and pricing plans for such services.
## Appendix 1

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Google’s Project Loon (Balloon Internet)</th>
<th>Facebook’s Aquila (Drone Internet)</th>
<th>OneWeb’s Low-Earth Orbiting Satellite Internet</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Local score ($W_i^c$)</td>
<td>Rank</td>
<td>Local score ($W_i^c$)</td>
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<td>Technical Superiority</td>
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<td>Network coverage</td>
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<td>Market Potential</td>
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<td>Profitability</td>
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<td>.296</td>
</tr>
<tr>
<td>Sustainability</td>
<td>.272</td>
<td>6</td>
<td>.288</td>
</tr>
</tbody>
</table>
Appendix 2.

Sky-streaming internet technology evaluation

Technological Superiority
$W_C = .353$

Socio-political acceptance
$W_C = .434$

Market Potential
$W_C = .319$

TV
$W_1 = .076$
$W_2 = .087$

CE
$W_1 = .089$
$W_2 = .095$

NC
$W_1 = .056$
$W_2 = .011$

TP
$W_1 = .082$
$W_2 = .006$

AA
$W_1 = .224$
$W_2 = .106$

LP
$W_1 = .138$
$W_2 = .087$

SA
$W_1 = .077$
$W_2 = .092$

PR
$W_1 = .083$
$W_2 = .020$

ST
$W_1 = .126$
$W_2 = .094$

EG
$W_1 = .126$
$W_2 = .043$

Balloon internet (Google’s Loon)
$W_C = .394$

Drone internet (Facebook’s Aquila)
$W_C = .283$

Low-earth orbiting satellite internet (OneWeb)
$W_C = .323$
References

Baldwin, P., & Thomas, L. (2005). Promoting private sector investment and innovation to address the information and communication needs of the poor in Sub-Saharan Africa.


TheInternetExperts. When Drones and the Internet Meet. from TheInternetExperts http://www.attinternetservice.com/resources/internet-drones/


