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Google Loon: Balloon Powered Internet for All

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ABSTRACT

The world has acknowledged the opportunities and possibilities the Internet offers. The Internet has been considered as a global community that is not only convenient, but genuinely helps to improve many different and important aspects of life including education, health, and economy. Sadly, only around 1/3rd of the global population at present has access to it. Providing cost-effective and efficient connectivity to rural areas is a very challenging task that has been given many different solution models over the years. One solution model that seems to offer a substantial business case is based on the Google Loon project, which provides many advantages. In this paper, we've tried to give an overview of the Loon project and also highlighted some key finds and observations.

Keywords— *UAV, Google Loon, LTE, Internet for all*

1. INTRODUCTION

The internet has altered the way we communicate, exchange ideas, and how the world does business. Nowadays most people are using the internet for most of their work, it can be said that the internet is one of the most essential aspects of everyone's life. But still, there are areas where the infrastructure for proper internet has not been made available. Providing internet access is still considered one of the major ultimatums at the global level. Still, one-third of the world population doesn't have access to proper internet connectivity, precisely the rural and remote areas. The main reason is that it is not feasible to lay telecommunication lines all around. Since the developing or underdeveloped countries cannot afford such a huge amount of money to lay fiber-optic cables, this would not be an ideal solution.

Connectivity is about people, places, and things. And while it feels like connectivity is pervasive, billions of people still have no means to basic internet access [1]. And while connectivity becomes one of the many essentials to our day-to-day lives, the growth of internet access is deteriorating, leaving billions of people unable to connect to the internet or have only infrequent, discontinuous access. To solve this global problem, Google has come up with an innovative solution called the "LOON", to provide broadband in rural and remote areas, as well as to improve communication during and after a natural disaster or a humanitarian crisis. A high-altitude platform would be an ideal solution to provide internet access to rural and remote areas around the world which can help them be a part of the digital revolution that could boost their finances, ameliorate their education system, and improve health. Loon is a fanatical approach to enlarging Internet connectivity to such areas. Instead of extending the Internet from underground, Loon uses the air medium i.e., the sky via a network of balloons, traveling through the edge of space, to facilitate internet connectivity to rural areas, fill coverage gaps, and improve network recovery in the event of a disaster [2].

The area coverage for a terrestrial cell tower is restricted by the height of its antennas. By elevating these antennas up into the stratosphere layer, and mimicking balloons as floating base stations, Loon has come up with an incredible idea of providing connection to the internet to a much larger area.

2. BACKGROUND, MOTIVATION AND RELATED WORKS

The use of flying platforms commonly referred to as unmanned aerial vehicles (UAVs), such as drones, balloons, small aircraft and to name a few are rapidly growing. In particular, with their innate characteristics such as adaptive altitude, flexibility, and mobility, UAVs disclose many key possibilities in wireless systems. UAVs can be used as aerial base stations to improve the security, coverage, capacity, and energy efficiency of traditional wireless networks. Nonetheless, UAVs can work as floating mobile terminals inside a cellular network. Such cellular-connected UAVs can serve many applications from real-time video streaming to sending and receiving a simple email. Especially, when UAVs are used as floating, aerial base stations, they can subsidize the connectivity of existing ground wireless networks such as broadband and cellular networks, as compared to traditional, ground base stations, the advantage of using UAVs as floating base stations is their capacity to avoid barriers, to balance their altitude and enhance the likelihood of establishing Line-of-Sight (LoS) communication links to ground users (Table I shows a detailed difference between UAVs and ground BSs) [3].

Table 1: UAV Base Station v/s Ground Base Station

UAV Base Station	Ground Base Station
Three-dimensional deployment	Typically, a two-dimensional deployment
Frequently changing and short-term deployment	Long-term, permanent deployment
Mobility Dimension	Fixed and static
Can reach a large, unrestricted area	Few, selected area

One of the main motives for Google to employ the LOON project was the use of UAV i.e., balloons in the stratospheric layer to provide airborne global Internet connectivity. Another motive was to utilize the abilities of the stratosphere layers, which are about 20Km above the Earth's surface and twice as high as where a commercial aircraft can operate. This height is enough for large network coverage footprints and low enough to aid low latency, high-speed data transfer. To date, the stratosphere has not received much attention outside research and academics. This is because it was considered not suitable for large commercial operations. As the pressure, temperature, gravity waves, solar radiations, wind speeds have harsh conditions for long-duration flights.

3. WHAT PROJECT LOON IS?

Project LOON was a research and development project developed by company X (formerly called Google X), with a mission to provide high-speed internet access to places where using the internet is still a dream. LOON delivers connectivity and unlocks the opportunities provided by the underutilized stratospheric layer. The first pilot testing was launched in June 2013 in New Zealand, with 50 initial users.

The primary object used in the development of this project is a balloon, which is placed at high-altitude around 20km from the earth's surface i.e., in the stratosphere layer. These balloons are constructed and designed in a way so that it can endure the harsh stratospheric surrounding, where winds blow above 100 km/hr, and temperature falls as low as -90° C. Each balloon can distribute connectivity to the ground area of around 40km in diameter and can provide 4G speed to its users.

4. LOON ARCHITECTURE

The Project consists of three main separate systems, namely the Balloon Envelop, the Bus, the Payload. Together, they work in coordination to provide elevation, observe flight measurements, and provide connectivity.

4.1. The Balloon Envelop

This is the inflated part of the system, the Balloon Envelop is made of polyethylene with about 0.076mm thickness, each balloon envelope is of a tennis court, and it actually consists of a balloon inside of a balloon. These balloons are filled with Helium/Hydrogen, when it is inflated to its full size, it is approximately 15m wide and 12m tall. A fixed amount of lift gas in the inner balloon keeps the system up in the air. Adding or releasing outside air to the external balloon changes density, allowing the system to go up or come down when needed. These balloons are built to last for hundreds of days before landing back on Earth in a controlled descending [4].

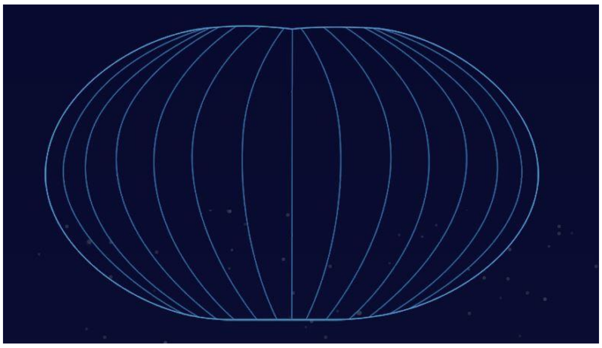

Fig. 1 Loon Balloon Structure

4.2. The Bus

The bus consists of the hardware and electronic units necessary for safe flight operations, which includes a highly efficient array of solar panels that power the system, an altitude control system for navigation, and a parachute that deploys automatically to direct the balloon safely back to Earth after the flight [4]. For added safety, Loon includes dispensable satellite communication links and transmitters for continual visibility to air traffic control [4]. The solar panels in the Bus can generate approx. 100W of power in full sun, and this is enough to keep Loon running and also charging a battery for using it at night. The system moves with the wind and charges the solar panels in the sun, Loon is able to power itself using renewable energy sources. While the balloon is moving along with the wind and charging in the sun, it is able to power itself using only renewable energy sources. Lithium-ion batteries are accustomed to save solar power so the balloons can operate throughout the night.

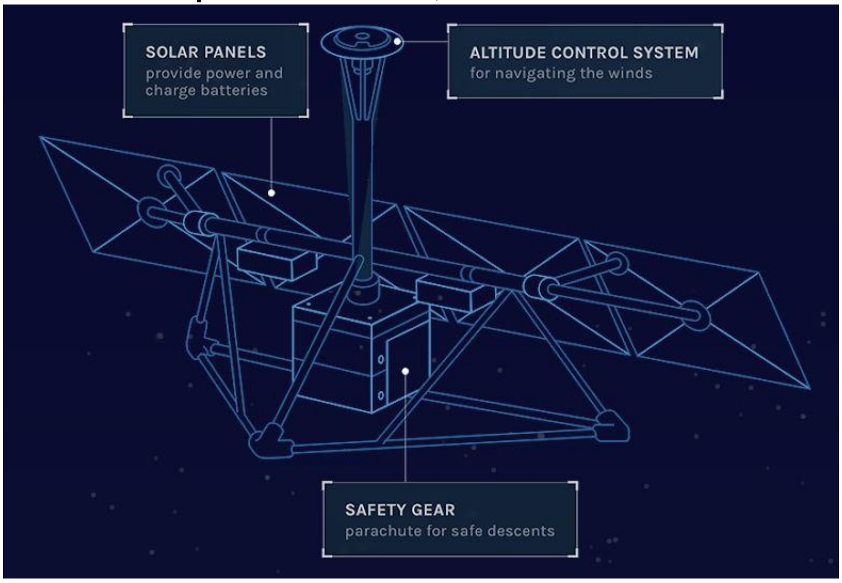

Fig. 2 Loon Bus Structure

4.3. The Payload

The payload consists of the communication equipment that is required to deliver connection, including the radio base station and antennas [4]. This equipment helps measure the flight system acceleration, take temperature measurements.

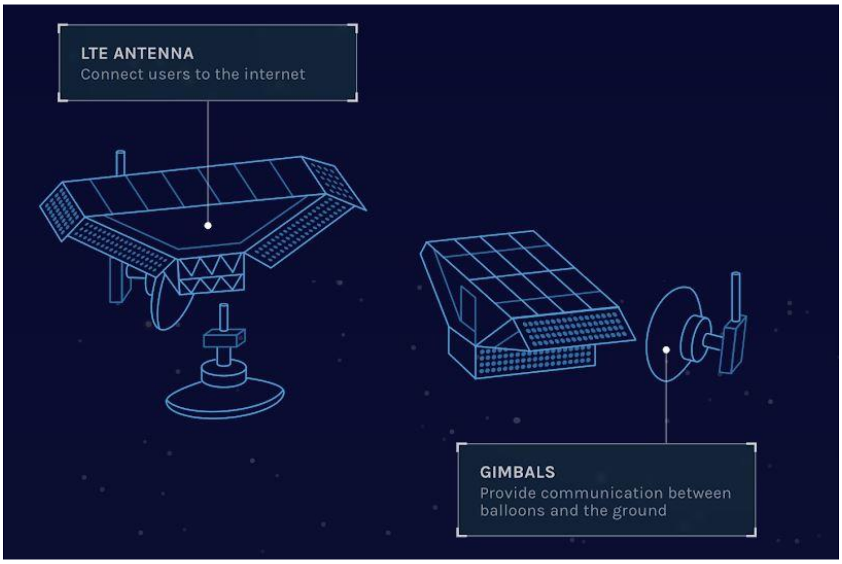

Fig. 3 Loon Payload Structure

5. WORKING OF LOON

The foremost layer of Earth's atmosphere is the troposphere, where we live and where most weather happens. The Loon balloons float in the next layer above, referred to as the stratosphere. The bottom end of the stratosphere begins between 6KM to 20KM above the surface of the planet, and the upper stratosphere ends at around 50KM above the Earth. The Loon balloons float between 18KM to 27KM up, which is almost twice as above as aviation routes. In this layer, there is little water vapor, very few clouds, and no weather to speak of. The temperature toward the bottom is also colder and that toward the top is hotter, which stops the gases from rising, generating a situation where there are moderately stable layers at different altitudes. At these layers, the wind blows in various directions and speeds in a predictable way. While in flight the system gets historical wind-related data and in-progress future forecasts from the National Oceanic and Atmospheric Administration (NOAA) to come up with algorithms that can predict and mimic wind patterns, which assists with balloon navigation [14]. The balloons will be guided by regulating the helium to air ratio in order to raise or lower them within the stratospheric layer where the wind is blowing in the direction system needs them to go [14]. They will be lifting rides on the wind, making them both solar and wind-powered in a sense [14]. Thus, with the help of the wind the balloons move and create one large communication network. Each balloon is provisioned with a GPS to track its location. Complex algorithms help direct where the balloons in the network go, then moves each one into a layer of wind blowing in the correct direction.

In order to connect to the Loon network, a special internet antenna is attached to the building/wall. It resembles a red balloon-like structure, with two main components namely a radio, which is in the bottom section, and the antenna which is placed in the upper section. The antenna consists of cables that are used for connecting the radio, which is a large disc-like structure with a silver reflector and a green square-shaped antenna. The large disc-like reflector decides the actual profile of the signal and is also a critical component. This is because as the Loon Balloons floats on the above surface they do not remain at a constant or fixed distance from the ground-based antenna at all time. Unlike the satellite dish antenna that can be aimed in a particular direction to hit the satellite, as most of the geostationary and communication satellites rotate around the earth at the same rate that it revolves, and they basically stay in the same spot overhead. With the balloons, they are drifting overhead, and a fixed, pointing dish is not going to work. They will be further away when they are not directly overhead, ad as they glide overhead, they will become closer and then move further away again. So, the antenna actually has to have more susceptible to an angle than it does straight up. That results in a uniform signal strength nevertheless where the balloon is overhead [5].

6. KEY FINDINGS AND OBSERVATIONS

Much of the analysis done for the paper is based on how the Loon has impacted the traditional Terrestrial LTE network. Specifically, if Loon could be used alongside the terrestrial network by providing adequate coverage in areas the terrestrial network could not cover. Loon only has a modest inimical impact on the existing terrestrial LTE network while enhancing coverage in areas where terrestrial LTE coverage doesn't exist. When a new cellular base station gets deployed in an LTE network it will generate some interference with the adjacent cells. Loon is no different. However, in a study conducted by "Signals Research Group", it was detected that Loon's presence in weak terrestrial coverage areas since the Loon signal strength was usually below -100 dBm. Additionally, self-interference within terrestrial LTE sites, which is common in an LTE network, existed even in the absence of Loon while Loon's contribution to interference in the LTE network was somewhat similar to the interference created by other terrestrial cell sites. The self-interference in the terrestrial network was also present in areas with strong RSRP while Loon's impact on the terrestrial network was often restricted to a small region of the network – outside that region, Loon provided coverage where the terrestrial network coverage was not sufficient or the Loon signal strength was adequately below the terrestrial network that it had the least effect on the terrestrial LTE network. It can be said that in the absence of Loon, the quality of the signal in the terrestrial network was no different than the signal quality with Loon.

The User Experience with Loon was amazingly good. Apart from data speeds and latency, Loon's performance with popular mobile data applications, such as web browsing, video chat, YouTube, and downloading applications from Google Play. Web page load times were very equivalent with Wi-Fi and LTE – occasionally a bit faster and occasionally a bit slower. The study conducted by "Signals Research Group", their experience with streaming 360p and 720p videos was agreeable with minimal buffering, but despite the fact that the video start time took a little too long as compared to the terrestrial LTE network (2x20 MHz channel bandwidth) and Wi-Fi. Likewise, the download times with Google Play took a bit more time with Loon as compared to the terrestrial LTE network, but it is an inequitable comparison since the Google Play (and YouTube) tests took place in Tarapoto, Peru where the operator has LTE deployed in Band 4 (2x20 MHz channels) and the Loon testing was conducted in a region where terrestrial LTE coverage didn't exist. Testing was also conducted with video chat calls (Google Duo) back to the United States from Peru, and while the quality of the video was not as bad as we experience when we use video chat applications at home, it was decent without any evident video freezes or audio dropping.

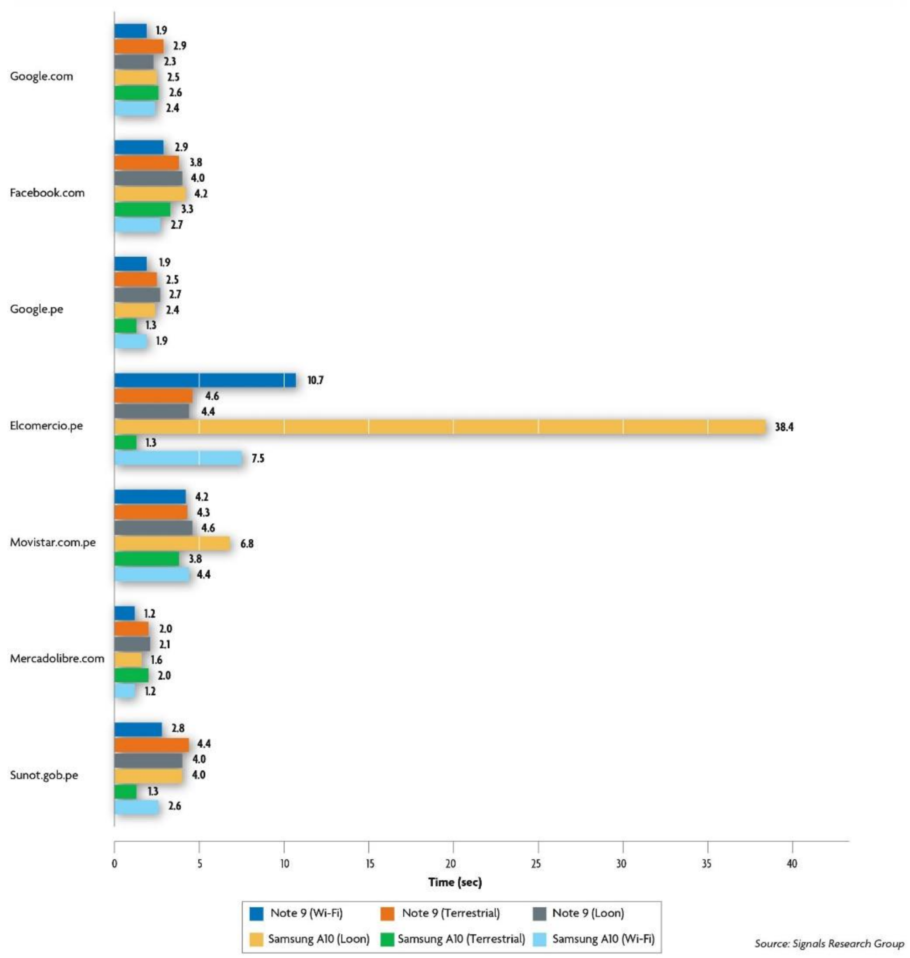

Fig. 4 User experience with Loon v/s Terrestrial Network with web browser [11]

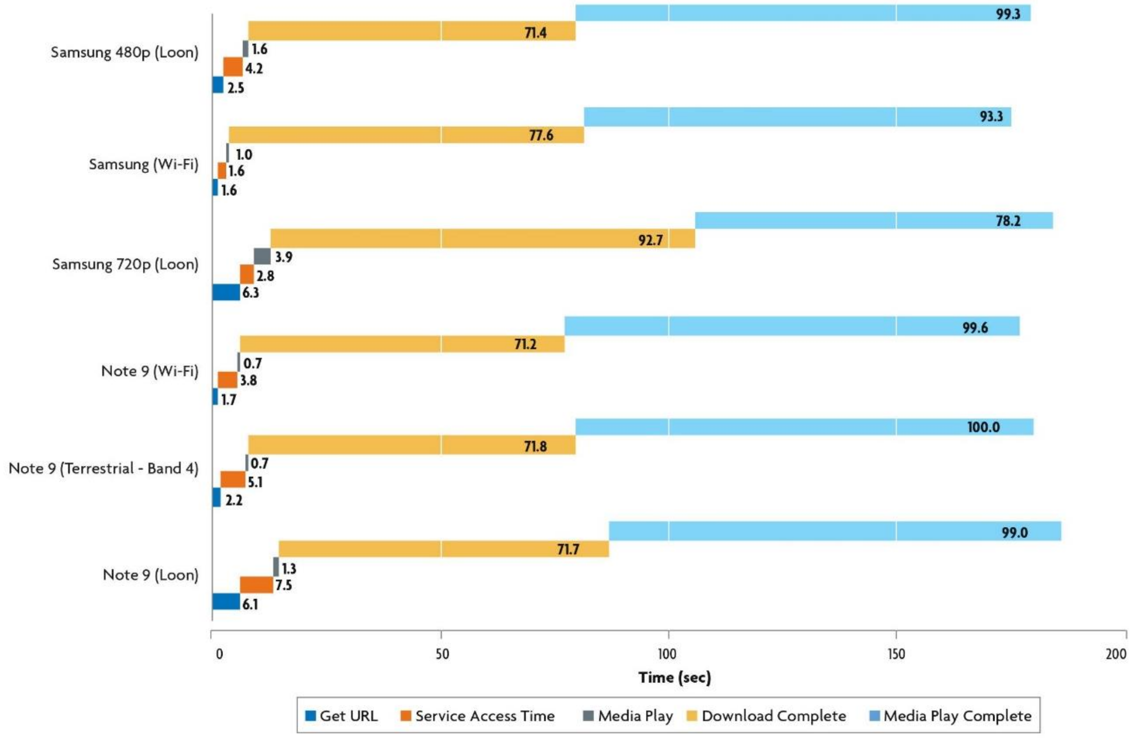

Fig. 5 User experience with Loon v/s Terrestrial Network with YouTube[11]

7. CONCLUSIONS

This project aimed to provide cost-efficient internet facilities to rural and remote areas, and also to provide a global connectivity solution in terms of mobile network expansion, disaster preparedness, and network orchestration. Google has utilized the power of the stratosphere to deliver connectivity.

The signal quality in the terrestrial network in the absence of Loon was no different than the signal quality with Loon [13]. Using Loon, the latency was only 13% higher than the terrestrial network, but the transmission power was much higher using the Loon network as compared to the terrestrial network [13].

When switching between networks it takes roughly 2 seconds for the mobile devices connected to the terrestrial network and it took just roughly around 20 milliseconds to move between Loon networks [13]. Basically, it can be said that Loon enhances the power of the terrestrial network by providing sufficient coverage in areas where the traditional terrestrial network can't cover and also reducing the interference between the two adjacent networks [13].

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