Analyzing "Global Access to the Internet for All" Projects

Sascha Rushing
Betreuer: Edwin Cordeiro
Seminar Future Internet WS2015/16
Lehrstuhl Netzarchitekturen und Netzdienste
Fakultät für Informatik, Technische Universität München
Email: sascha.rushing@tum.de

ABSTRACT

The world has acknowledged the opportunities and possibilities the Internet offers. It is not only a convenience, but genuinely helps to improve many different and important parts of life, such as education, health and economy. Unfortunately only around one third of the world's population currently has access to it. The open research group *Global Access to the Internet of All* (*GAIA*) is an initiative of the *Internet Research Task Force* (*IRTF*), with the goal that in the near future everyone is provided with affordable Internet access. This paper will introduce the most promising projects related to *GAIA*, including Google's *Project Loon*, *internet.org* by Facebook, Microsoft's approach using TV whitespaces and *Community Networks*. Additionally, proposals concerning how the chair *Network Architectures and Services* of the Technische Universität München could contribute regarding its field of research will be presented.

Keywords

IRTF, GAIA, Internet for all

1. INTRODUCTION

1.1 Motivation

The Internet has grown to be a fundamental part of everyday life. Sending emails to colleagues, video-chatting with family or checking the latest sports results at home on the computer or via smartphones on the go. The Internet has created an entirely new way of communication and information exchange, connecting societies all around the globe.

Unfortunately this privilege is still not accessible to everybody. Even though the number of internet users is increasing, only around 40% of the entire world's population is online. This means that about 4 billion people do not have access to the Internet, with more than 90% for those from developing countries[1].

Figure 1 visualizes this issue. The size of the countries embodies the amount of people with Internet access, whereas the color (ranging from white to dark red) depicts the percentage of the population. As stated earlier and visible in the image, the developing countries are very poorly connected.

The *Global Internet User Survey 2012* conducted by the *Internet Society* interviewed over 10.000 internet users across 20 different counties. Its goal was to provide general information on the behavior and opinions of internet users about various topics regarding the Internet. The majority of the participants agreed, that the internet plays an important role in their everyday life concerning subjects such as knowledge, education, health, economy and many others. Furthermore 83% of the interviewees agreed that internet access should be considered a basic human right.[3] The initiative *Global Goals* by the United Nations released in September 2015 also includes the desire for universal and affordable Internet access in least developed countries by 2020.[4]

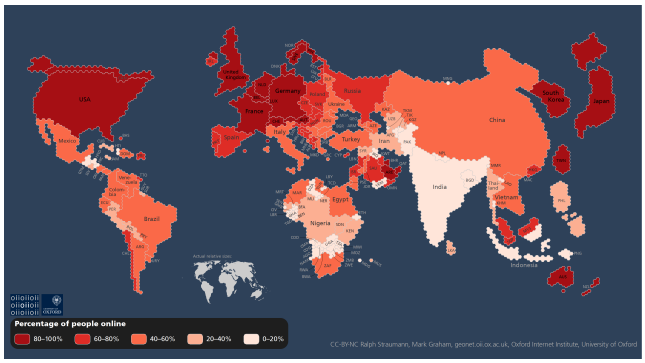

Figure 1: The world online[2]

With this information in mind, the question why so many people do not have Internet access arises. Building broadband internet infrastructure can be very costly, especially if the population is scattered across huge areas. Because of this low cost effectiveness Internet Service Providers (ISP) do not pursue this issue.[5]

Another problem is the pricing and affordability of Internet. In developing countries access costs can be as much as 40 times their national average income. Even in more developed countries this can be an issue, due to unstable financial circumstances people cannot commit to a lengthy broadband contract.[5]

This paper presents a research group and its most promising ideas to try and make Internet access possible for everyone.

1.2 Internet Research Task Force (IRTF)

The *Internet Research Task Force* (*IRTF*) is a research group focusing on internet related topics. It consists of multiple sub groups investigating specific subjects concerning Internet protocols, applications, architecture and technology. In contrast to the *Internet Engineering Task Force* (*IETF*), a parallel organization dedicated to short term subjects of engineering and standard making, the *IRTF* commits to long-term related research. Any committed individual can con-

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tribute and participate.[6]

Since the creation of *IRTF* in 1989, 25 research groups have been chartered and concluded their activities. As of September 2015, there are a total of nine active research groups.[7]

1.3 Global Access to the Internet for All (GAIA)

One sub group of *IRTF* is called *Global Access to the Internet for All* (*GAIA*). It was chartered on October 15th 2014, as a result of the *The Internet Society's Global Internet User Survey 2012*[8], which revealed that a majority of the participants classify Internet access as a basic human right[3]. As the name let's one suspect, its research focuses on solutions that will provide Internet access to everyone.

The *Global Access to the Internet for All* (*GAIA*) initiative is officially defined by the following six goals[8]

1. "to create increased visibility and interest among the wider community on the challenges and opportunities in enabling global Internet access, in terms of technology as well as the social and economic drivers for its adoption; "
2. "to create a shared vision among practitioners, researchers, corporations, non-governmental and governmental organizations on the challenges and opportunities; "
3. "to articulate and foster collaboration among them to address the diverse Internet access and architectural challenges (including security, privacy, censorship and energy efficiency); "
4. "to document and share deployment experiences and research results to the wider community through scholarly publications, white papers, presentations, workshops, Informational and Experimental RFCs; "
5. "to document the costs of existing Internet Access, the breakdown of those costs (energy, manpower, licenses, bandwidth, infrastructure, transit, peering), and outline a path to achieve a 10x reduction in Internet Access costs especially in geographies and populations with low penetration. "
6. "to develop a longer term perspective on the impact of *GAIA* research group findings on the standardization efforts at the *IETF*. This could include recommendations to protocol designers and architects. "

2. PROPOSALS

2.1 Google - Project Loon

Project Loon is an initiative by Google. The first pilot tests were launched in June 2013 in New Zealand. The core concept of *Project Loon* is the use balloons in the stratosphere with an altitude of approximately 20 km as wireless connection points. It utilizes the phenomenon that the winds in the stratosphere are stratified, meaning they are layered with each layer having a different wind direction and speed, as shown in Figure 2.[9] Controlled by one large communication network, the balloons can be arranged as to evenly cover a desired area. This is done by altering the balloon's altitude and moving it to a different wind layer, which in turn will carry the balloon to its designated position.[9] The

Figure 2: *Project Loon* utilizes the properties of stratified winds in the stratosphere.[9]

wind data for these calculations is provided by the *National Oceanic and Atmospheric Administration*(*NOAA*).[10]

These high altitudes provide unique advantages, but they also create particular engineering challenges. As the balloon rises up in the air, the air pressure and temperature are constantly decreasing. At its optimal altitude air pressure is only 1% of that at sea level, with temperatures around -50°C. Additionally, due to the thinner atmosphere, the balloons are exposed to more direct UV light. To ensure that the balloon does not pop, all these factors have to be taken into consideration in its design.[11] Currently balloons can last for up to 100 days, before deliberately descending down to earth[9]. Besides these technological issues, there are political concerns as well. Many countries may not want to be dependent on a U.S. located company, due to the current status of their relationship with the United States of America.[12]

On the other hand there are very positive things concerning the altitude of the balloons. The winds in the stratosphere are fairly steady with 8 - 32 km/h, which enables controlled position alteration. Furthermore, they are well over commercial airplane altitudes as well as weather phenomenon. This ensures that the balloons can move freely with little danger of collision.[11]

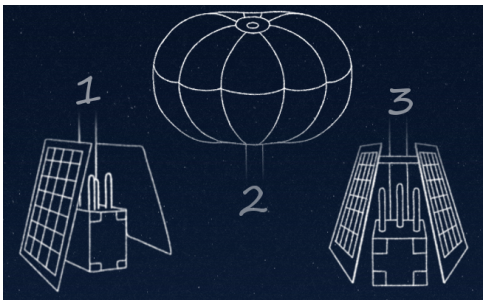

Figure 3: Main components of a balloon 1) solar panels 2) envelope 3) electronics[9]

Each of these solar powered balloons, consisting of three main components as shown in Figure 3, can cover a ground area up to 40 km in diameter. Specialized antennas enable two kinds of connections. Firstly, with other balloons in the mesh network and secondly, with the end user or ground station connected to the internet.[11]

Google has developed antennas which can be installed

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outside of buildings, for example at home or the work place. In the beginning, these antennas establish a wireless connection via ISM (industrial, scientific and medical) radio bands, using 2.4 and 5.8 GHz. These frequencies are not governmentally owned and unlicensed around the world, which saved Google from frequency negotiations and purchase. The end device in turn could be connected via Wi-Fi to the local antenna. The same method is used to establish a connection between the balloons and a ground station, connected to an internet backbone. Google claimed they were able to reach speeds equivalent to 3G.[11]

As of now, Google has pursued another connection approach using a communication technology called LTE, for which Google partnered with various telecommunication companies. Using the cellular spectrum, every phone or LTE-enabled device will be able to connect directly to the balloon covering the area.[9]

Now that the user can connect to the balloon network and the balloon network to the ground station, the only link missing is the connection between the balloons themselves. The official algorithm used by Google to control and manage their mesh network of balloons is disclosed. It is very probable that their approach builds upon a common method such as the IEEE 802.11s, which is a standard for mesh networking using many mesh points.[11]

2.2 Facebook - internet.org

internet.org is a project initiated by Facebook in partnership with various other companies, non-profit organizations and governments. The core of their idea is to tackle the problem of connectivity using a divide-and-conquer approach, as shown in Figure 4, for different population densities need different solutions. The goal is to create a wireless network, using *Free Space Optics* and radio waves [13], that can be received no matter where. The reason of using wireless over terrestrial technology is the justified by mainly two reasons. Building cell towers and fiber cable infrastructure requires physical construction, which may not be possible due to geographical reasons, or even prohibited due to regulatory approval. Another downside of terrestrial networks is their exposure to insecurities such as war or natural disasters.[14]

Depending on the population density and geographical possibilities, Internet access can be provided by either a radio mast, an unmanned aerial vehicle, a LEO satellite or a GEO satellite. Following simple laws of physics, each method has a different range and signal strength. The closer the device is to earth, the stronger is its signal, yet the smaller is the area it can cover. A relatively forward approach is the use of satellites. Unfortunately the costs of building and shooting them into space are still very high. They will undoubtedly be important to provide connectivity in remote locations, but cannot be used to create a continuous network.[14]

To overcome this issue, Facebook is currently researching a similar approach as Google's *Project Loon*. Instead of using balloons, unmanned solar powered drones called *Aquilla* are to be used, as depicted in Figure 5. They are made of carbon fiber and have a wing span of around 42 meter, which is roughly the size of a Boeing 737. These 400 kilogram heavy, v-shaped crafts will too, like Google's balloons, be stationed at an altitude of approximately 20 km.[13] Facebook is confident that drones are a better solution than balloons as they claim that drones can fly towards their desired position more accurately. Additionally they think that the drones can return to earth more easily for maintenance, creating the opportunity of a cost effective method.[14]

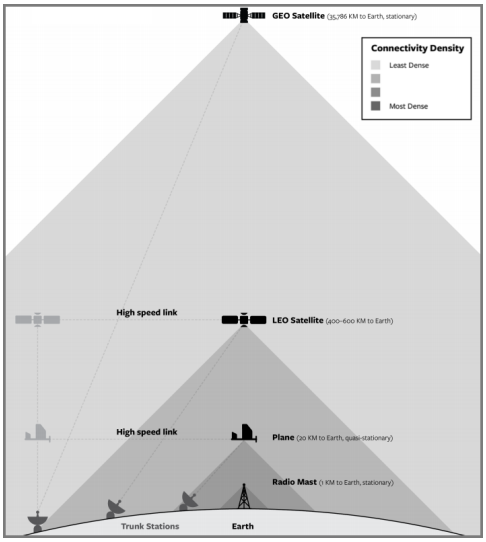

Figure 4: Divide-and-Conquer approach by internet.org[14]

Figure 5: Facebook's solar powered drone, Aquilla.[13]

Solely providing Internet access is not enough if the connection speed is too slow. To overcome this problem, Facebook is working on improving a wireless transmission technique called *Free Space Optics* (*FSO*)[14].

FSO is a procedure of transmitting optical signals through free space of air. To propagate these optical signals through air *FSO* uses light, generated by either LEDs or lasers. The concept of *FSO* transmission can be compared to regular optical transmission using fiber-optic cables, the only difference being the medium they use. In the case of fiber-optic cables light travels through glass, with a speed of approximately 200,000 km/s. *FSO*, using air as the transmission medium, has a speed of around 300,000 km/s, the speed of light. The projected beam size at the receiving end is a lot bigger than at the transmitter. Meaning the shape between the transmitter and receiver is rather equal to a cone than a straight line. This implies that not all the information is arriving at the receiving end. This phenomenon is called *geometric path loss*. To reduce this effect, by making the beam

narrower, the transmitter and receiver should have fixed positions.[15]

Unfortunately there are still other drawbacks to the *FSO* method, such as obstruction by physical objects. This is not the case when using cables, since they do not need to be laid out in a straight line between transmitter and receiver. Another issue, taking into account that the transmitters (drones) are in the stratosphere, is fog and clouds. The humid air conditions have a huge impact on light, as the water can absorb, scatter or reflect it, which interrupts the light beam and breaks the connection.[15] For this reason, Facebook is working on a combination of *FSO* and radio waves as a compromise for bad weather conditions.[13]

Public reactions to the *internet.org* project have been very mixed and Facebook has been criticized on what their internet will offer. The main issue is that Facebook reserves the right to only give access to a selected amount of websites and not the entire internet.[16] On May 18th 2015, an open letter concerning these issues has been sent to Mark Zuckerberg. This letter was signed by many international organizations including Germany based *Digitale Gesellschaft* and *Förderverein freie Netzwerke e.V./freifunk.net*[17].

2.3 Community Networks

In contrast to relying on networking structures provided by companies such as Google or Facebook, *Community Networking*, often referenced as *bottom-up networking*, is built and operated by citizens for citizens. In this model of the Future Internet communities build, operate and own open IP-based networks, meaning that anybody who wants to participate can join and therefore increase the size and connectivity of the network. With the help of non-profit organizations managing these networks, it is possible to develop a variety of different services for these networks including local networking, voice connections and Internet access.[18]

Since anybody can participate in these networks, they can be of very large scale. Additionally they are distributed and decentralized as well as very dynamic, for people can join but also abandon the network at any time. The main components of *Community Networks* are nodes which are linked with each other, either wirelessly, using IEEE 802.11a/b/n technology, or via fiber cable. Due to the convenience of installing wireless equipment in contrast to terrestrial construction, wireless technology is mostly used. The nodes are owned and maintained by members of the network, with the only requirement being the acceptance of the peering agreement such as the *Pico Peering Agreement*[19], with the purpose of diminishing participation barriers.[18]

There are already many of such *Community Networks* up and running all around the world. One of the biggest is located in Spain called *Guifi.net*, which consists of over 20,000 nodes.[18] The German initiative *freifunkt.net* is distributed all over Germany, present in currently 209 cities and towns. Each community has its own website including information, such as a live map of all connected nodes and more importantly on how interested persons can join the project. There are also regular meetings to help new members get started, by supporting them getting their equipment configured and installed.[20]

There are still a lot of open research questions concerning *Community Networking*. A research project, called *community-lab* initiated in 2011, is investigating various properties of these networks, which include IEEE 802.11a/b/n connectivity and interference problems, privacy issues and many more.[18]

The idea of *Community Networking* is not only of use in combination with actual Internet access, but as well in secluded locations using an "Internet in a box" approach. This means that each network contains its own content and services only available in that particular network. It is not connected to the actual Internet. Unlike the way we know it, the content of this network is not stored on servers, but on mobile devices owned by the people of the community, such as smartphones, tablets and laptops. The main requirement of these devices is the availability of either a Wi-Fi or Bluetooth module and a moderate amount of persistent memory.[21]

The way content is distributed in the network can be compared to human verbal interaction. If two people are close to each other they can talk and exchange information. After going separate ways, these two individuals can in turn talk to new people, passing on the information gathered from their previous conversation partner. This way information is spreads arbitrarily.

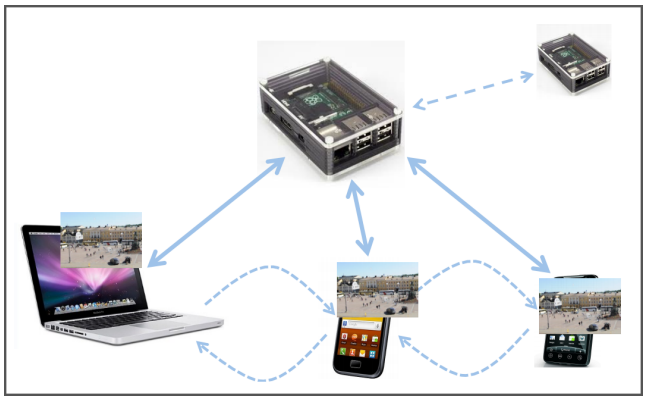

Figure 6: Content is being shared between devices and Liberouters[22]

The mobile devices follow the same principle. If two devices are close enough to each other, they establish a Wi-Fi or Bluetooth connection with each other and exchange content saved on their persistent memory. Since all the information available in the network is stored on these portable devices, storage space is a very limited yet vital resource. To ensure that one's device is not being "polluted" with uninteresting content, it is possible to *subscribe* to certain content and information categories, filtering what will actually be downloaded and saved to the device's persistent memory.[21]

Considering persistent memory availability, connection distances and battery issues mobile devices alone may not be enough. Public access points, via so called *Liberouters*, distributed in various often visited places can help solve this problem. A *Liberouter* contains a USB flash drive on which information can be stored. Via Wi-Fi connection mobile devices can exchange information with the *Liberouter*, downloading new, subscribed to content as well as uploading information gained from other *Liberouter* or devices as shown in Figure 6. *Liberouters* are made of Raspberry Pis, a WLAN module and a flash drive, creating a very affordable solution for approximately 80 Euro.[21]

Even though this approach is fairly simple, it can have

a huge impact on various parts of life in remote locations. For example, in a farming village farmers can subscribe to weather data gathered by a local weather station, which can help increase the harvest. The local news can be distributed like this as well, giving everyone the chance to be up to date on local events. Sectors like healthcare, education and many others would also gain a lot by this distribution method.

2.4 Whitespaces

Due to the complexity of terrestrial Internet access construction, it has become obvious that wireless connectivity in rural and remote areas is a lot more cost effective. This can be done by using the IEEE 802.11 standard, *Free Space Optics* or other radio bands. The problem when using the electromagnetic spectrum is licensing. Most frequencies are strongly regulated by either governments or companies and can therefore not be used.[23]

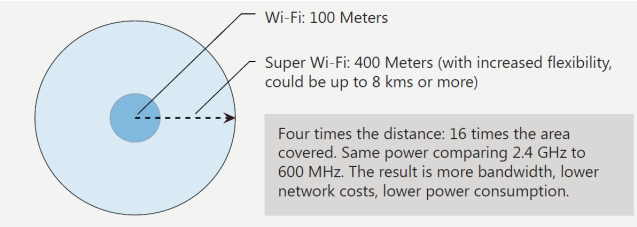

Figure 7: TV whitespaces can cover a considerable larger area than regular Wi-Fi.[24]

In analog TV transmission, broadcasting channels cannot use frequencies continuously, due to interference issues. This means that there has to be a "gap" between two channels, leaving certain frequencies unused. These empty channels are referred to as *white spaces*[23]. They can be used, similar to Wi-Fi, to establish an Internet connection. Comparing the Wi-Fi and TV whitespace frequencies, the latter can service an area 16 times the size of the Wi-Fi range. This means that fewer access points are needed to provide internet access for a larger region. Another advantage of TV whitespaces are their penetration, meaning that they are not as easily obstructed by physical objects, such as walls. Due to its properties TV whitespaces are often denoted as *Super Wi-Fi*.[25]

Microsoft has been actively researching the field of TV whitespaces for the last couple of years. They have been involved in many projects with other companies and governments to provide internet connectivity with this technology. Most of which were conducted in Africa, but there have also been projects in Asia and South America.[26]

2.5 Others

Virtual Public Networks. Even though Internet access is available in an area, it does not mean that everyone has the ability to use it. As the *Nottingham Citizens Survey 2011* revealed, affordability is also a very genuine issues in developed countries[27]. Since most households do not occupy their entire bandwidth at all times, the remaining capacity could be shared. This approach is realized in *Virtual Public Networks* (*VPuN*), splitting the connection into best (home user) and less than best effort (guest user) connections.[27][28]

Social Wi-Fi: Hotspot Sharing with Online Friends. Making one's WiFi connection openly accessible to others can bear risks, such as the sharer being accountable for illegal actions of the guest user. To prevent the probability of harmful guest users *Social WiFi* makes use of the high online social network penetration. Only people who are friends or contacts on social networks (e.g. Facebook, LinkedIn, Google+, etc.) can automatically connect to your network and make use of your Internet access.[29][30]

A4AI - Alliance of Affordable Internet. *A4AI* is a global initiative, composed of private sector, public sector, and civil society organizations dedicated to making Internet access affordable for everyone. Their ultimate goal is to decrease Internet access costs to less than 5% of monthly income.[31] *A4AI* is rather a political than technological initiative, trying to shift policies and regulations in order to create a competitive and innovative broadband market.[32]

Traffic Optimization. Traffic optimization can help save bandwidth usage, airtime in wireless networks and therefore energy. This will be an important part of creating high performance Internet accessibility in remote locations, which only have limited resources at their disposal. A new approach of optimizing network traffic is called *Simplemux*, which is a generic multiplexing protocol.[33][34]

Local Initiatives. There are various programs and projects actively working on getting the world online, such as *AirJaldi* in India[35] and TUCAN3G in Peru[36].

3. TECHNISCHE UNIVERSITÄT MÜNCHEN

3.1 Chair of Network Architectures and Services

The chair for *Network Architectures and Services* at the Technische Universität München focuses on topics in the field of Telematics, the combination of telecommunication and informatics. This includes issues concerning network security, peer-to-peer communication, mobile communication, high speed networks and many more.[37]

The following section will provide ideas on how the Technische Universität München, in particular the chair for *Network Architectures and Services*, could contribute to the *GAIA* initiative with their research.

3.2 Contribution Proposals

3.2.1 Recent Publications

IP Spoofing. IP spoofing describes the action of forging the source IP address in packets. This is done to increase anonymity on the Internet, but also to impersonate other sources.[38] It is therefore a big issue concerning authentication and DoS attacks. The chair has been involved in investigations regarding this problem and how to implement spoofing protection for firewalls.[39]

This could be a very interesting topic concerning the Google balloons and Facebook drones. With so many new Internet users the occurrence of such attacks will very likely increase.

A potential research project could be a spoofing protection implementation for these aerial crafts, for packets coming into the "local network", "local" meaning all end users connected to one particular craft, as well as packets leaving the "local network" into the mesh network and therefore the Internet. Successfully filtering all packets in the craft firewall will ensure that only relevant and honest packets will use the resources and bandwidth of the mesh network. Due to the fact that these aerial crafts are moving and the users connected to it will vary, the filtering criteria will have to change dynamically. The findings of the chair state that the introduced approach can process thousands of rules within a second, which would make this method possible.

Software-based Packet Processing. Another topic the chair has been actively researching is software-based Packet processing. Instead of using rather expensive dedicated hardware, software-based Packet processing runs on commodity and therefor cheaper hardware.[40]

In *Community Networking*, more specifically freifunk München the Wlan routers use a Linux-based operating system called OpenWrt instead of readymade firmware.[41] OpenWrt does not provide too much functionality, but offers the ability of adding packages to obtain new functionalities.[42]

The chair could get involved in creating a package for OpenWrt concerning packet processing. Fast packet processing is especially vital in networks where only a few routers act as a bridge between two bigger clusters. Additionally, mobile devices can also be used as nodes. Here it could also be of interest to the chair to investigate packet processing on mobile devices concerning power efficiency and performance.

Digital Certificates. The *TUM Secure E-Mail* project aims to increase the security and privacy of email communication using OpenPGP and S/MIME digital certificates. A currently open thesis topic attends the issue of how the certificate management could be handled.[43]

In local *Community Networks* (Internet-in-a-box approach) data is being distributed via various Liberouters and devices, granting everyone access to all the information. To ensure privacy in this kind of setup, a certificate approach similar to the *TUM Secure E-Mail* could be used. The fact that these networks do not have a stable connection to some sort of server calls for a creative solution, for example using one specific Liberouter as a certificate manager in the town's city hall.

3.2.2 General Field of Research

Authentication and Anonymity. One of the main research fields of the chair is network security. This includes methods for authentication and security protocols as well as privacy and anonymity on the Internet.[44]

These topics are an essential part of *Community Networking*. As mentioned in section 2.3, anyone can participate in *Community Networks* and increase its size and connectivity. This implies that there are literally a lot of "men in the middle", who could easily intercept and access data sent or received by users in the network. Even though the interference and modification of data is strictly prohibited by the peering agreement[19], it does not mean that ever member of the network will abide by it. The results of the chair's research could help improve those security issues.

Traffic Measurement and Analysis. The chair is involved in research about traffic measurement and analysis. By analyzing the measured data, malicious activities as well as malfunctions in the network can be detected. Additionally the chair contributes to standardization bodies, particularly to the *IETF*, a parallel organization of the *IRTF*.[44]

The outcomes of this study could help to improve the arrangement of the *Project Loon* balloons and Facebook drones. Depending on various factors of the traffic, the crafts have to obtain new positions as to react to the current demand. In order to have low responds times, the traffic has to be analyzed accordingly and in a timely manner.

4. CONCLUSION

It has been officially acknowledged that the Internet should be accessible to everyone, not just one third of the world's population. Internet access was not only rated as a basic human right by the *Global Internet User Survey 2012*, but was also addressed more recently in the *Global Goals* initiative by the United Nations in September 2015. Open research groups like *GAIA* try to tackle this public problem as a community. Many global players are also working on solutions to make this idea reality, for example Google and their *Project Loon*, Facebook with internet.org and Microsoft using TV whitespaces. Even individual citizens are making an effort in solving this issue, as seen in *Community Networks*. The future concerning global access to the Internet for all looks very promising and hopefully someday soon it will not only be an idea anymore, but reality.

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