International Partnership on Innovation

SAMS - Smart Apiculture Management Services

Deliverable N°3.6

Report on Data Communication

Work package N° 3 – HIVE-System

Horizon 2020 (H2020-ICT-39-2017)

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SAMS consortium partners

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giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH	Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH (Coordinator)	GIZ	Germany
UNIKASSEL VERSITÄT	University of Kassel	UNIKAS	Germany
KARL-FRANZENS-UNIVERSITÄT GRAZ UNIVERSITY OF GRAZ UNI GRAZ	University of Graz (Institute for Biology)	UNIGRA	Austria
Latvia University of Life Sciences and Technologies	Latvia University of Life Sciences and Technologies	UNILV	Latvia
iceaddis	ICEADDIS – IT-Consultancy PLC	ICEADDIS	Ethiopia
IQQO Oromia Agricultural Research Institute	Oromia Agricultural Research Institute, Holeta Bee Research Center	HOLETA	Ethiopia
Universitas Padjadjaran	University Padjadjaran	UNPAD	Indonesia
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List of Abbreviations

DSS	Decision Support System
DW	Data Warehouse
ICT	Information and Communication Technologies
IoT	Internet of Things
MCU	Microcontroller unit
PLC	Powerline Connection
2G/3G	second and third generation cellular network technologies
SD card	Secure Digital card
SDG	Sustainable Development Goals
UCD	User Centered Design
M2M	Machine to Machine communication

Summary of the project

SAMS is a service offer for beekeepers that allows active monitoring and remote sensing of bee colonies by an appropriate and adapted ICT solution. This system supports the beekeeper in ensuring bee health and bee productivity, since bees play a key role in the preservation of our ecosystem, the global fight against hunger and in ensuring our existence. The high potentials to foster sustainable development in different sectors of the partner regions are they are often used inefficient.

Three continents - three scenarios
(1) In Europe, consumption and trading of honey products are increasing whereas the production is stagnating. Beside honey production, pollination services are less developed. Nevertheless, within the EU 35% of human food consumption depend directly or indirectly on pollination activities.

(2) In Ethiopia, beekeepers have a limited access to modern beehive equipment and bee management systems. Due to these constraints, the apicultural sector is far behind his potential.

(3) The apiculture sector in Indonesia is developing slowly and beekeeping is not a priority in the governmental program. These aspects lead to a low beekeeper rate, a low rate of professional processing of bee products, support and marketing and a lack of professional interconnection with bee products processing companies.

Based on the User Centered Design the core activities of SAMS include the development of marketable SAMS Business Services, the adaption of a hive monitoring system for local needs and usability as well as the adaption of a Decision Support System (DSS) based on an open source system. As a key factor of success SAMS uses a multi stakeholder approach on an international and national level to foster the involvement and active participation of beekeepers and all relevant stakeholders along the whole value chain of bees.
The aim of SAMS is to:

- enhance international cooperation of ICT and sustainable agriculture between EU and developing countries in pursuit of the EU commitment to the UN Sustainable Development Goal (SDG N°2) “End hunger, achieve food security and improved nutrition and promote sustainable agriculture”
- increases production of bee products
- creates jobs (particularly youths/ women)
- triggers investments and establishes knowledge exchange through networks.

Project objectives

The overall objective of SAMS is to strengthen international cooperation of the EU with developing countries in ICT, concentrating on the field of sustainable agriculture as a vehicle for rural areas. The SAMS Project aims to develop and refine an open source remote sensing technology and user interaction interface to support small-hold beekeepers in managing and monitoring the health and productivity in their own bee colonies. Highlighted will be especially the production of bee products and the strengthening of resilience to environmental factors.

- Specific objectives to achieve the aim:
- Addressing requirements of communities and stakeholder
- Adapted monitoring and support technology
- Bee related partnership and cooperation
- International and interregional knowledge and technology transfer
- Training and behavioral response
- Implementation SAMS Business cooperation

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Executive summary

The endless opportunities we are facing in this so-called revolutionary time is knocking on our door right now. Humanity is challenged to leave the old platform of second industrial revolutions which power by fossil fuel-based energy. Leave us with new challenges to lit up and make way for the new platform that fuels by renewable energy and *aggregate efficiency*[1], with interconnection of all things in between. This condition can be achieved if we can make use of the advancing technology the world offer right now. Equipping components and machinery with sensors and software makes it possible to acquire field data automatically. Interconnection means this data can be retrieved in near real-time and collated at a central point. What could previously be seen directly at the components and machinery on the shop floor can now be visualized and monitored using software on a single platform. The result is maximum transparency. All data is provided at the application level, making it easy to see if there is a problem or deviation and then determine the exact nature of the problem or deviation. This enables considerably reduced response times and increases effectiveness.

This report covers information on the data communication process within the implementation phase of the SAMS HIVE monitoring system. The data communication process cannot be separated from any other aspects of the whole project, like businesses and product development, and identified users. How and what data is being communicated at any time depends much on the background of the targeted users. Several options regarding network and coverage to maintain the data communication process is also identified, including options for data package types despite regulations and conditions applied in each country (prepaid, postpaid, Machine to Human data package, or Machine to Machine data package). All of these aspects are needed to be taken into consideration for the development of SAMS as a useful product in the future. Lastly, the challenges which the SAMS consortium identified during the process combined with the lessons learned and recommendations are presented at the end of the report.

1 “Aggregate efficiency is the ratio of potential work to the actual useful work that gets embedded into a product or service. The higher the aggregate efficiency of a good or service, the less waste is produced in every single conversion in its journey across the value chain.” -*Jeremy Rifkin, economic and social theorist.*

1. SAMS Data Communication

The picture bellow illustrates in a simplified manner the data flow from the source (the sensory hardware), via the transmitter to the data warehouse, and lastly, to the receiver (the end-user). It is directly linked to the SAMS beehive data process.

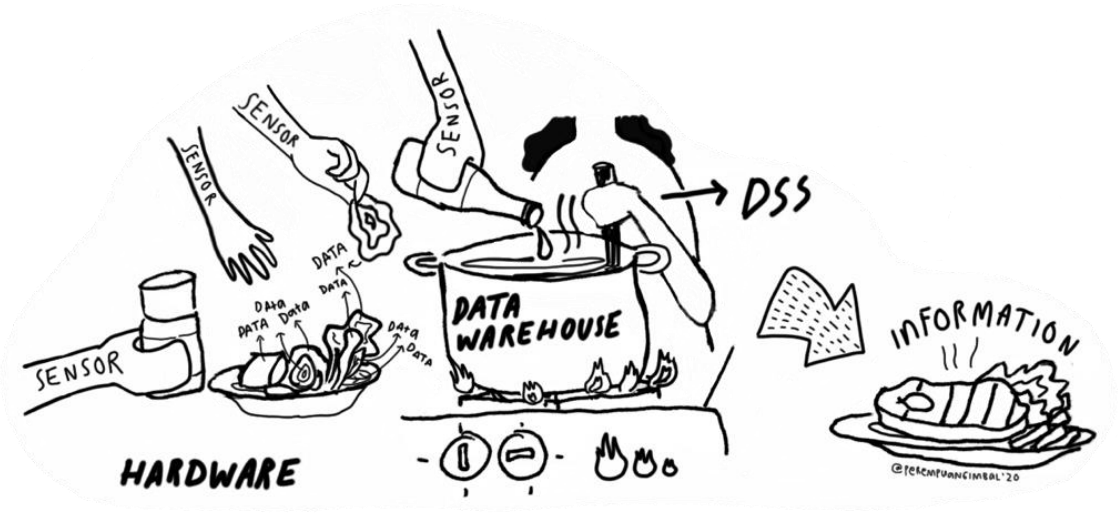

Figure 1. Illustration of data communication

The SAMS HIVE monitoring systems collect data from remote locations, mainly in Ethiopia and Indonesia but also in Europe, from several sensors like temperature sensors, weight sensors, humidity sensors, and sound sensors. Each sensor is being read by a single board computer (Raspberry Pi Zero W or NodeMCU, in the SAMS case). Ideally, the data is automatically transferred via the mobile network (2G/ 3G) to the SAMS Data Warehouse, which is located in Jelgava, Latvia. But when the monitoring system is offline, recorded data is being stored on a system integrated SD card, and locally collected by a partner beekeeper or transferred to the Data Warehouse at a later time, when the network is more stable. In the case of SAMS, the SD card must be at least 16 GB to be able to host the software image for the remote download. The Github image is free and public available online.

Transferred data runs through the DSS (Decision Support System) that interprets the data, recognizes specific patterns according to the implemented algorithms, concludes what is happening inside the beehive and informs/ notifies the beekeeper by providing specific recommendations.

These conclusions in the form of “information” are then consumed by SAMS users. This whole process is what counts as SAMS Data Communication. Stability of the system’s firmware, internet accessibility, and locations of the apiaries of SAMS beekeeper partners are significantly related to the success of the communication process.

2. Data Consumer

How and on which platform the data is being communicated depends on who will consume the data. SAMS data consumers vary depending on the specific characteristics, for example, the education level of the target users, availability of internet access in the country, and exposure of the tech start-ups ecosystem and knowledge. For grassroot beekeepers who struggle to read and used to do beekeeping activity based on passed down tacit knowledge and instinct, too much data details and written recommendations are not valuable for them. Meanwhile, for entrepreneurs or tech start-ups society (economic community) who exposed to the possibility of how technology could be used to leverage effectiveness, such information would be appreciated. In the case of SAMS, these two user groups are considered as SAMS target user groups, but the differences in their backgrounds may affect how SAMS should communicate its data and information. The development of the apiculture industry and supports from important stakeholders also plays an important role in the data consumer readiness.

Data collected within the SAMS project can be of use to several target groups and communities. The SAMS project team has distinguished four main user groups of SAMS data consumer: beekeepers, scientists, economic communities (such as entrepreneurs, tech start-ups in agriculture), and the general public (such as makers community, creative community, environment activist, etc). These main users were identified based on the applied User Centered Design (UCD) approach, during internal partner discussions and consultations with SAMS advisory board members. Not every party can use datasets in a raw format though, to some consumers, only analyzed data or selected data will be of value.

Table 1. Matching of needs and properties of SAMS data consumer

Properties of SAMS Data	Beekeepers	Scientists	Economic community	General public
Bee colony temperature	X	X		X
Bee colony weight	X	X	X	X
Bee colony status	X			
Environmental parameters	X	X		X

For further analysis of data usability for SAMS main user groups go to Deliverable 6.3 Transfer Study on Data Utilization, under chapter 2, “Usability and benefits of SAMS data for DW users and third parties”.

Though in each country the focus target user groups remain the same, some background differences influenced the readiness level of each target user group in consuming and utilizing SAMS data. Several factors that influence the differences, to name a few are the maturity of the apiculture industry, government support, and age structure (children & young adolescents,

the working-age population, and the elderly population). The more mature the apiculture sector in one country, the bigger the support given by the government, the more resources flow, the more flourishing the industry will be. The bigger the working-age population in one country, the more labor available, the more industries are thriving. The working-age population factor is also believed as one of the main factors that determine the growth of the creative industry. In 2018, the working-age population in Indonesia is 67,59%[2], Ethiopia 55,26%[3], and Europe Union 64.69%[4].

Table 2. Level of factors influenced the target user group in each country

	Indonesia	Ethiopia	Europe Union
Apiculture industry maturity			
Government support in apiculture industry			
Working-age population			

Table 3. Level of readiness in consuming data for each target user group in each country

	Indonesia	Ethiopia	Europe Union
Beekeepers			
Scientist			
Economic community (entrepreneurs, tech start-ups in agriculture, etc)			
General public (makers community, creative community, environment activist, etc)			

2 https://www.statista.com/statistics/319214/age-structure-in-indonesia/
3 https://www.statista.com/statistics/455134/age-structure-in-ethiopia/
4 https://www.statista.com/statistics/253408/age-distribution-in-the-european-union-eu/

A closer look at each target user group analysis in each country will be available in Deliverable 2.2 User-Centered Design Results and Lessons Learned (coming in October 2020).

3. The Communication and Transfer Process

All data collected by the SAMS monitoring system's sensors are sent to the Data Warehouse in Jelgava, Latvia. The SAMS Data Warehouse (DW) is a universal system, which can operate with different data inputs, such as direct data transfer from bee colony monitoring devices, manual data upload, and has flexible data processing algorithms based on the incoming data sets. The SAMS DW can be linked not only to the SAMS monitoring devices but also to other general bee colony monitoring systems. By the definition, the Data Warehouse is like an intermediate layer between data provider systems and data consumer systems or end-users. It is used to help beekeepers run the apiary more effectively by utilizing a higher amount of available data, and accumulated data interpretation knowledge is developed as a cloud-based data storage and processing unit with capabilities to combine different data sources like existing systems and available on-apiary generated data.

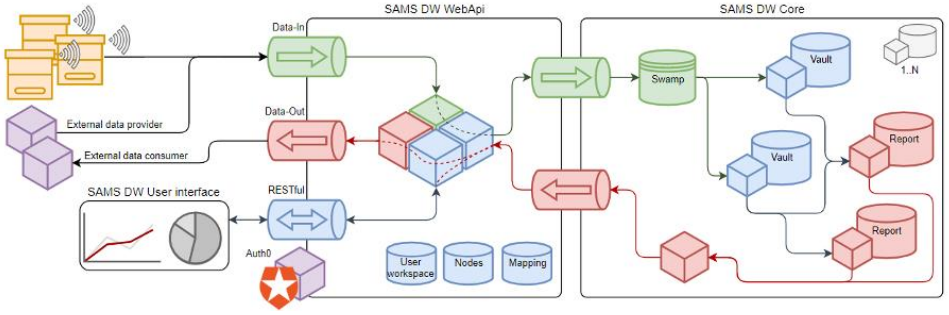

Figure 2. The Architecture of the SAMS Data Warehouse

The SAMS Data Warehouse is already developed and is a fully operational platform and can easily be accessed from any web browser (except outdated ones, like Internet Explorer). SAMS bee colony monitoring devices, or any other monitoring devices, can directly be connected to the SAMS DW and transfer and store the data. A description of the SAMS DW base and its containing parts (as well as their interaction) is provided in deliverable on Report on Data Management (D4.1).

To succeed in communication between the SAMS HIVE monitoring system and the Data Warehouse, data network packages are needed. There are types of data package availability and usability. Depending on how to pay for the usage of the data, there is prepaid and postpaid data package available from telecommunication companies. Apart from how to pay, there are also types of how the communication is made, and the network is used; Machine to Human communication and Machine to Machine communication.

Machine to Human Communication is a form of communication in which humans co-work with Artificial Intelligence (AI) systems and other machines as opposed to utilizing them as tools or

devices[5]. The concept of letting the machines interact with humans based on either voice or gestures is called machine to human interaction. The usual Machine to Human network package is mostly catered to consumers' needs to communicate and socialize with smartphone devices in daily life.

Machine to Machine Communication or M2M is exactly as it sounds: two machines are “communicating,” or exchanging data, without human interfacing or interaction. This includes serial connection, powerline connection (PLC), or wireless communications in the industrial Internet of Things (IoT). Switching over to wireless has made M2M communication much easier and enabled more applications to be connected. M2M communication often referring to cellular communication for embedded devices[6]. Examples of M2M communication, in this case, would be vending machines sending out inventory information or ATMs getting authorization to dispense cash, or the SAMS HIVE monitoring systems sending data to enable precision beekeeping.

3.1 Indonesia

In the prototyping phase of the project, when implementing the SAMS HIVE monitoring systems in March 2019, prepaid Machine to Human connection is being used to transfer data to the Data Warehouse. At that time, there was no obvious option for data network packages other than Human to Machine types of network. Nevertheless, as more systems are produced, challenges arise with this kind of prepaid Machine to Human connection package. In Indonesia, for every SIM card activated, it must be registered under a personal ID (passport number or other identification numbers), for its purpose to serve human interaction. Other than that, the data package is available only in big bytes. Whereas the SAMS system only needs 10 MB per month per system, and the usual Machine to Human package smallest options are usually around 3 GB per month. The obligation to register under a personal ID number is quite a challenge since it is impossible to register all SAMS systems under the consortium members’ ID.

To overcome such challenges, communication has been made with a local telecommunication company in Indonesia. Telkomsel is a state-own telecommunication company and long considered as the number one telecommunication company in Indonesia. As the first telecommunication company in the country, Telkomsel network coverage is considered the best, it can even reach remote areas in Indonesia, and has been used by most people in the country. It turns out that Telkomsel has a postpaid M2M package network. Unlike prepaid Machine to Human package networks that are available everywhere and easy to get, to obtain M2M SIM card, company registration and contract signing are needed. The M2M network has been testing out since mid-August 2020 and implemented with two of the SAMS HIVE systems. It could not be tested out sooner this year due to the outbreak of COVID-19 since March 2020. For several months, Indonesia’s government applying physical distancing regulations including encourage its citizen to stay at home and work from home. Around June 2020, some

5 https://evincedev.com/machine-to-human-communication/
6 https://www.link-labs.com/blog/what-is-m2m

regulations are started to loosen, and citizens are allowed to gradually get back to pre-pandemic routines. Even so, many terms and conditions are applied, and still, stay at home is being campaigned as the best option to take even until now. Regarding M2M data streaming testing, there are still some issues with the network connection settings which attempts on resolving it are being made continuously. More SAMS HIVE systems that will be implemented in the upcoming months will be using this M2M network package. The relationship established with Telkomsel will ensure the quality and signal strength to maintain permanent access to internet service.

3.2 Ethiopia

In Ethiopia, there are options for different data packages of which M2M is also available. But for SAMS, Machine to Human 3G/ 4G data package is being used. The main reason for using Machine to Human 3G data package for the SAMS HIVE monitoring system is because the SAMS monitoring system is based on the 3G network, while the current M2M data package from Ethiopian telecom is dependable on the 2G network and do not support 3G network. Currently, all SAMS HIVE monitoring systems implemented in Ethiopia are using postpaid data plan so that the amount of data can pass the limit on the initial plan, if required, with no hustle.

Network coverage and internet shutdowns are the main challenges to succeed in the data communication process in Ethiopia. The network system mostly shifting from 3G to 2G networks, causing the data transfer becomes very challenging. Sometimes it may take days to go back from 2G to 3G/ 4G network system. Meanwhile, internet shutdown is temporary and mostly caused by security/ unrest problems to block the circulation of fake news that may cause instability in areas under some turmoil.

3.3 Europe

Countries in Europe have different regulations regarding ID numbers registration for active SIM cards. For example, Belgium requires personal ID number registration to obtain prepaid Machine to Human package data SIM card, whereas Latvia does not have such regulations. In the Netherlands, the Minister of Justice announced in September 2016 that it would ban anonymous SIM cards. In Austria, there has been a discussion about the end of anonymous SIM cards as part of a new surveillance package. Below, European countries marked with red are countries that are requiring SIM card registrations, green areas are countries where SIM card registration with personal ID is not necessary, whereas yellow are countries in the process of finalizing the regulations.

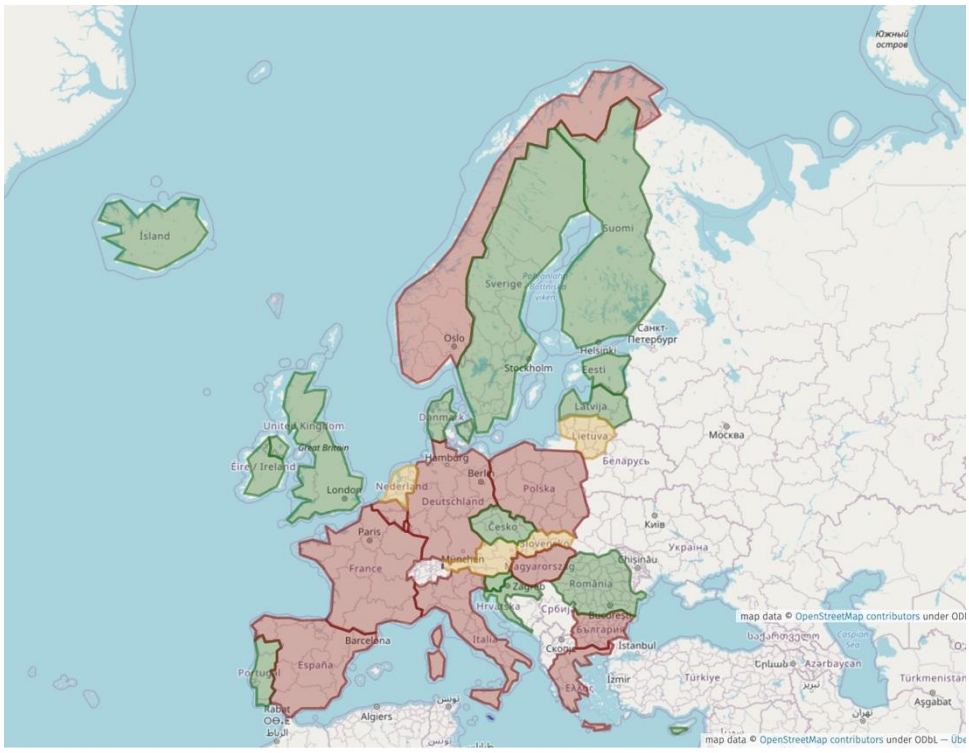

Figure 3. Maps of SIM card registration regulation in Europe

In the case of the SAMS project, prepaid Machine to Human data network packages are being used in Germany, and Machine to Machine data network packages are used in Latvia.

4. Challenges, Lessons Learned and Recommendation

As mention in the previous chapter, connectivity is mainly challenging in Ethiopia. Ethiopia's connection often unpredictably shifting to 2G, makes it difficult to maintain stable data streamed to the Data Warehouse. The provided router for the system cannot send data due to these mobile network problems. To overcome this network availability uncertainty, the SAMS HIVE monitoring system data should pass through 2G as well as 3G networks based alternatively. It was agreed that a router with capabilities to use the 2G network for data transmission will be used instead. Indonesia has a different case. Starting in the middle of July 2019 when the dry season started, many beekeepers were struggling with the colonies absconding. When the dry season lasted longer than it usually should, even more beekeepers were struggling with absconding. This affected the data transfer to the Data Warehouse since no data could be recorded in the empty beehives which last for several months. On the side note, both Ethiopia and Indonesia facing one other issue regarding the unstable previous firmware that is still in the development phase. This instability of the firmware causing some interruptions of data streaming. Since February 2020 firmware images are updated for several time, and still are developing up until now.

In summary, challenges that are encountered regarding data communication process in Ethiopia and Indonesia are:

- Network stability in Ethiopia, which the usability of the router with 2G capabilities is hoped to be able to solve the problem

- Lack of IT expertise for the application of a quick solution/ fixing of problems at the installation sites of Holeta and Gedo, causing the systems in Ethiopia are not operating
- Availability of healthy bee colonies during dry season (e.g. last year 2019) at partner beekeepers in Indonesia
- Instability of the firmware, which the development to better the performance is still progressing up until now

It is concluded that the option for local storage of measurements is necessary to mitigate the data transmission problems. Meanwhile, both partners from Ethiopia and Indonesia will continuously take actions to complete the implementation phase of the rest of the SAMS HIVE monitoring systems. Historical behavior of the colony will also be made available. To be able to gather offline stored data, partners from the Latvia University of Life Sciences and Technologies (UNILV) developed a solution for convenient offline data transfer from the local bee colony monitoring device to the flash drive.

Speaking of the data communication, in 2019 there are 184.94 million internet users in Indonesia[7], whereas 167.38 million are mobile internet users[8], which means around 90% of the internet users are accessing internet through their mobile devices. In Ethiopia, there are 21.14 million internet users, where 97% are mobile internet users[9]. In Europe, as of June 2019 Germany is the country with the most internet users (see figure 4), follow by United Kingdom, France, Italy, and Spain. 85 percent of European households had an internet connection in 2016. The share of households with internet access in the European Union (28 countries) grew by 30 percent compared to the share of connected households in 2007. An estimated 189.8 million people had a broadband internet connection in Europe in 2016. Roughly 56 percent of individuals in the EU-28 use a mobile phone to go online[10].

7 https://www.statista.com/statistics/254456/number-of-internet-users-in-indonesia/
8 https://www.statista.com/statistics/558642/number-of-mobile-internet-user-in-indonesia/
9 https://datareportal.com/reports/digital-2020-ethiopia
10 https://www.statista.com/topics/3853/internet-usage-in-europe/

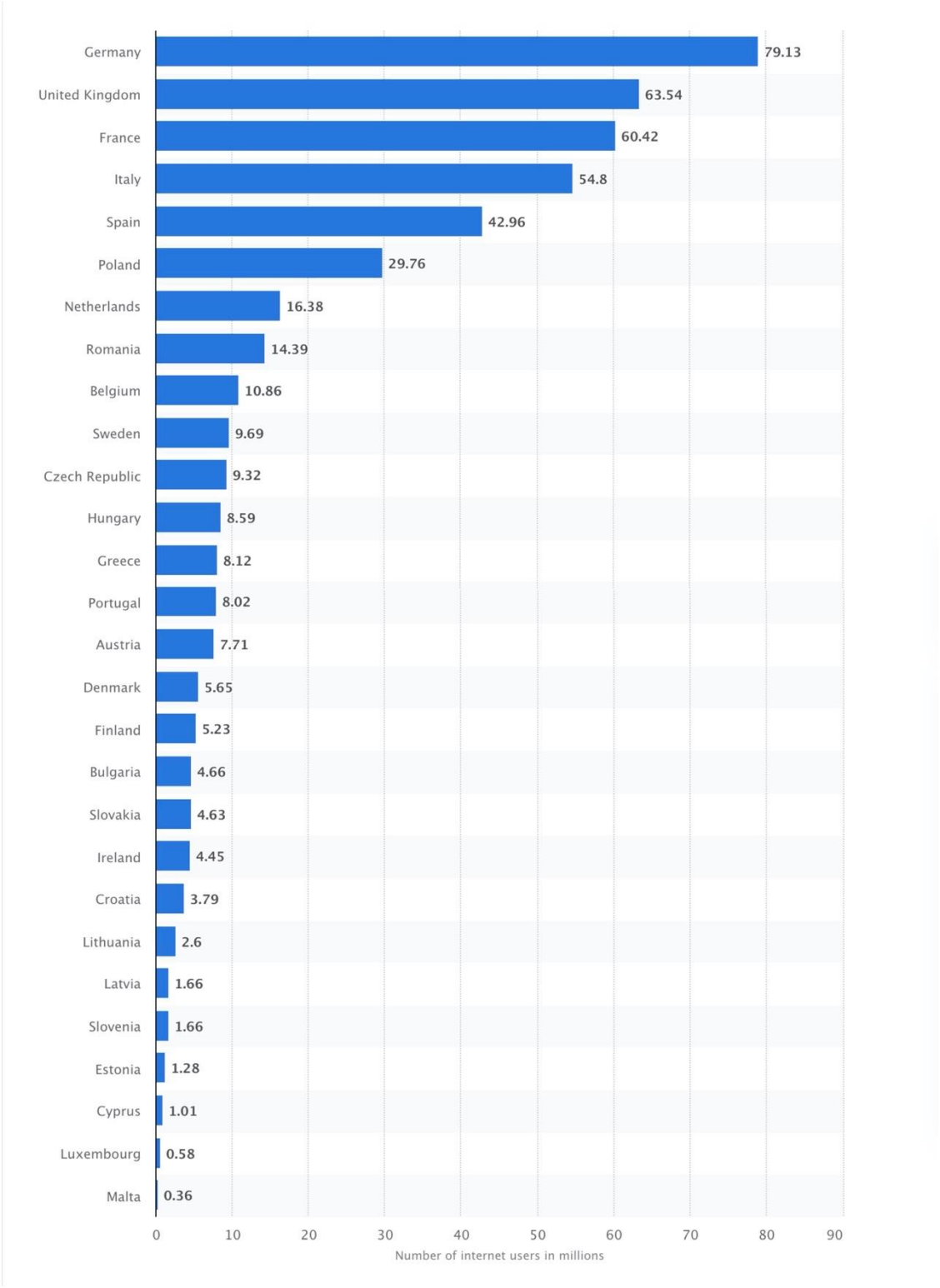

Figure 4. Internet Users in Europe Countries

Considering the number of internet users that access the internet through mobile devices, especially in Ethiopia and Indonesia, to guarantee the usability of the SAMS HIVE monitoring system, it is crucial for SAMS data can be accessed easily via mobile devices. The DSS (Decision Support System) interface which contains recommendations that play a role as main interaction with the users is now being iteratively prototyped and tested to the end-users (the

beekeepers) in Ethiopia and Indonesia. The system's implementation in Indonesia also better to focus on Java island, to guarantee stable connectivity. According to the map (see figure 5)[11], network coverage (Telkomsel) is quite secure on Java island, then Sumatera island came in the second position.

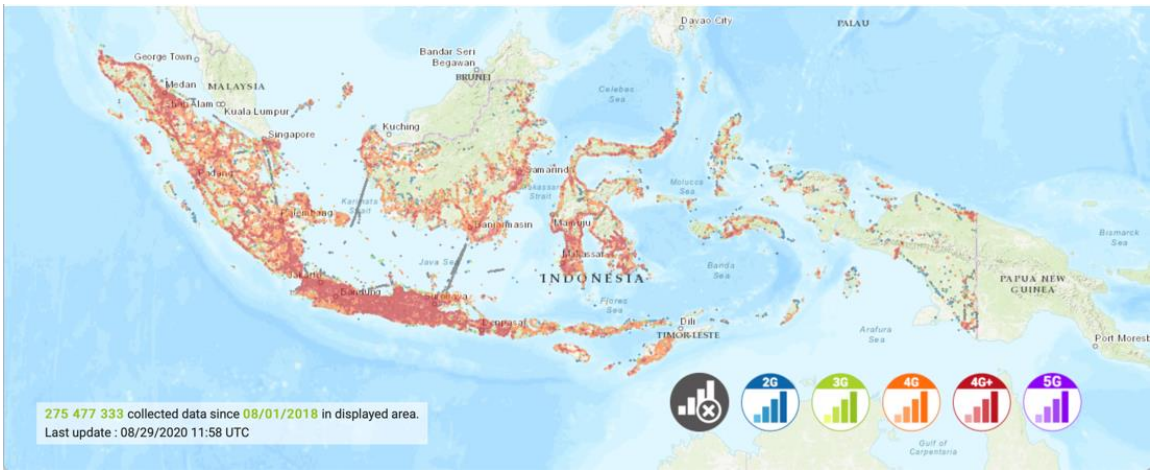

Figure 5. Maps of Network Coverage in Indonesia

11 Telkomsel user Map in Indonesia taken from https://www.nperf.com/en/map/ID/-/5119.Telkomsel/signal/?ll=-2.56789421643423 84&lg=118.01999999999998&zoom=5

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