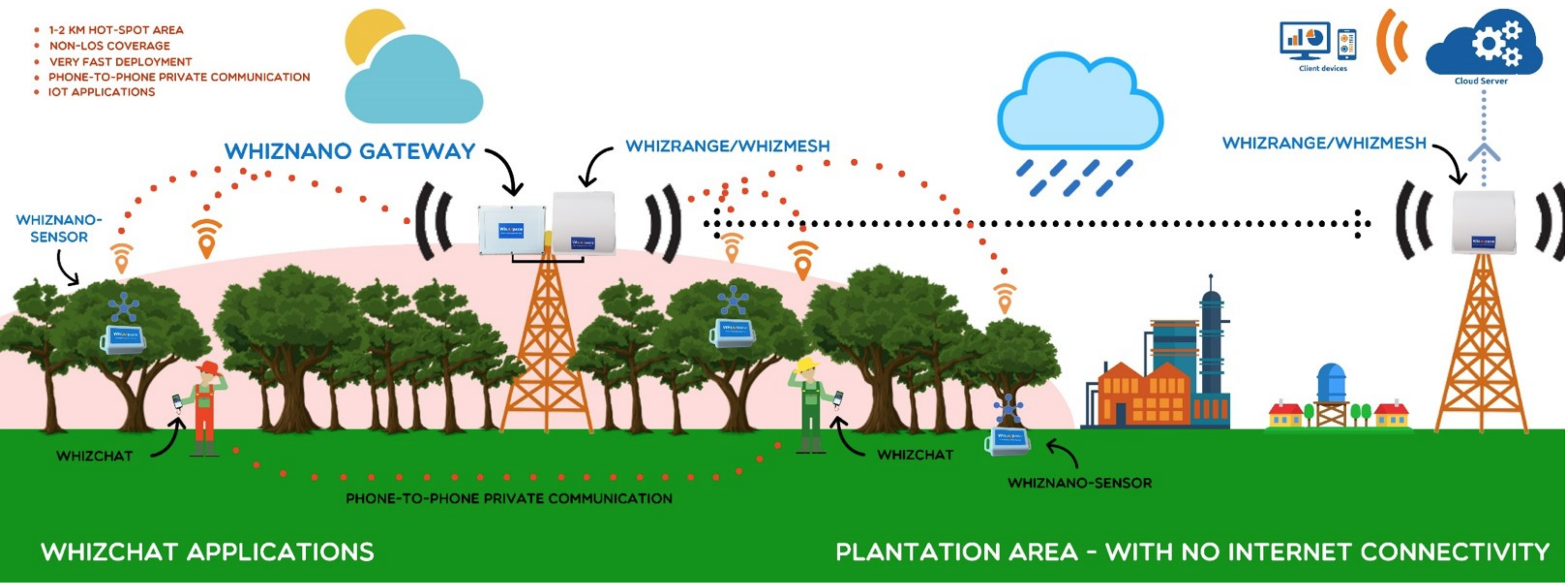
Precision Agriculture

using TV White Space



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EXECUTIVE SUMMARY

Agricultural sector is the world's largest industry generating around $3.178T of revenue globally as of 2016. However, there are still room for growth. Efficiencies can be improved, waste can be averted in order to meet the higher demand for livestock and crop with limited natural resources.

With most rural agriculture areas experiencing poor connectivity, there is a lack of necessary communications and informational device to aid productivity. Which in turn hinders the efficiencies of crop harvesting, livestock ranching and fish farming. Thus, in order to meet the high demand for food and reduce cost, an efficient connectivity need to be provided to these areas.

With the availability of suitable broadband connectivity, various agricultural technologies can be employed to increase efficiency. For example, drones can be used for monitoring of crops to collect necessary data to analyse crops. This allow farmers to be more well informed on their crops and livestock to make better-informed decisions about their harvest. In this way, farmers will be able to enjoy higher crop yield though optimization. Therefore, reliable low-cost connectivity serve as a vital stepping stone for the farmers in rural areas to enjoy a breakthrough in their productivity levels.

TV White Space (TVWS) provide better and faster connectivity at low cost especially in rural regions where it is inaccessible. TVWS leverage on available radio spectrum, empty channels in TV broadcast channels known as "White Spaces" to deliver what is known as "Super Wi-Fi. This Super Wi-Fi provides long range, good penetration through obstacles. In addition, the deployment and maintenance time is also lower as compared to other existing network.

Hence, with the availability of connectivity, farmers will be able to employ precision agriculture techniques to improve their farming process. Farmers will be able optimize their farming process to reduce wastage and finite resources, allowing sustainability of the environment and at same time, livelihood of mankind by producing more food.

This whitepaper discusses on the application of TVWS into the agricultural sector and how it would bring about many advantages such as higher productivity levels.

Contents

1.0 INTRODUCION

The agricultural sector plays a vital role in sustaining the livelihood of mankind by providing safe and reliable food supplies. Most importantly, agricultural sector also holds the capability to alleviate poverty in rural areas where agricultural activities contribute to most of their economic activities. A study done by OECD (Organisation for Economic Co-operation and Development) found out that agricultural sector contributes 52% to poverty reduction in developing countries [1].

As highlighted by OECD-FAO Agricultural outlook, there will be higher demand for food as population increases while in the face of climate changes and a fall in finite resources availability such as fertile land and water [2]. Therefore, there is a need to increase the productivity of the agricultural sector to ensure sustainability of mankind and the environment. Increasing productivity in the agricultural sector, however, this may not be an easy feat as food production system can be very vulnerable to the adverse impacts of climate change. Furthermore, the conventional technologies adopted previously may experience diminishing returns and natural resources such as fertile soil might face degradation. This problem can be alleviated by adopting productivity improving technologies such as drones, cameras or sensors to bring about higher crop yield.

However, in rural areas, connectivity is scarce in area with low population density due to the lack of financial incentives and presences of environmental obstacles. This led to building networks in such areas more expensive and complex, thus limiting the options for those living there. To aid such areas, new wireless technologies such as TV White Space (TVWS) solve this issue by providing low-cost and reliable connectivity suitable for the rural regions.

1.1 OPPORTUNITIES

Precision Agriculture has been enabled by the advancement in technology. With the use of Drones, GPS, Sensors and many others, Precision Agriculture define a decision support system for whole farm management with the goal of optimizing returns on inputs while preserving resources.

According to the research done by Huawei, governments and agriculture development authorities are cooperating with financial institutions, organizations and manufactures to promote growth of sustainable agriculture initiatives. This partnership provides an invaluable source of empowerment to the agriculture sector with more advanced technologies, improved management process and opening new revenue streams [3].

With the greater promotion for sustainable agriculture initiatives, it creates an opportunity for the different broadband providers alongside the support of the public and private sector.

2.0 MOTIVATION FOR PRECISION AGRICULTURE

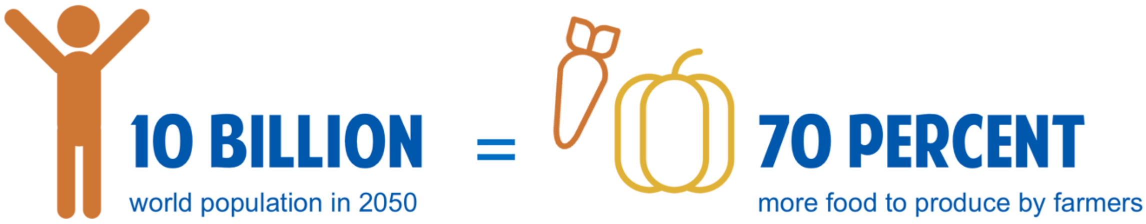


Figure 1: Demographics

As highlighted by Global Government Summit, there will be higher demand for food as the population increase rapidly due to urbanization which will require 70% more food to be produced [4]. However, there is a threat of global instability since arable acreage cannot keep up. Furthermore, many farmers in rural regions might lack the foresight for sustainable land management practises which lead to land degradation, soil erosion and overgraze rangelands on top of depreciation of resources. Hence, there is a need to boost the productivity of farms through alternative methods to ensure sustainability of mankind by meeting the high demand of food and preventing further environment degradation.

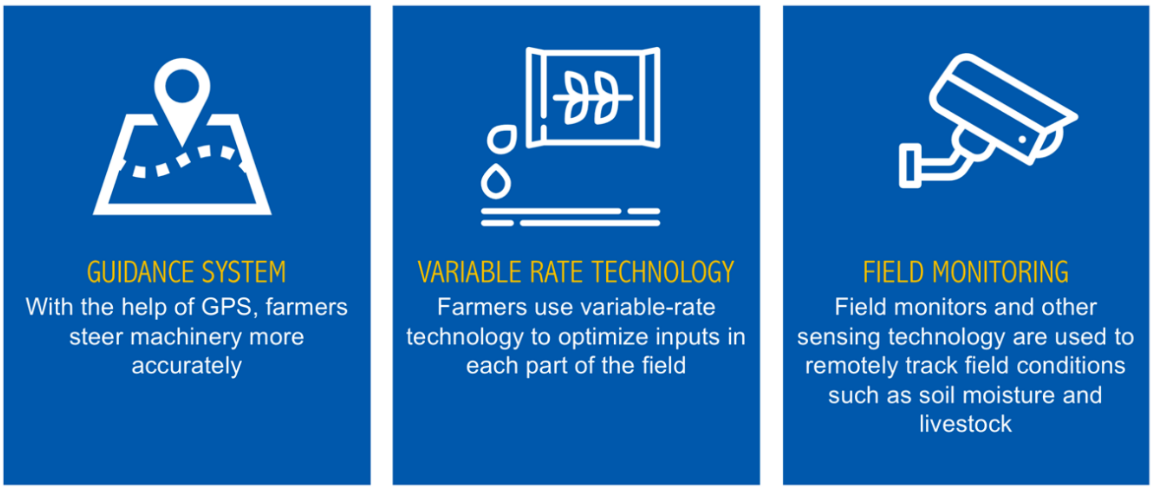
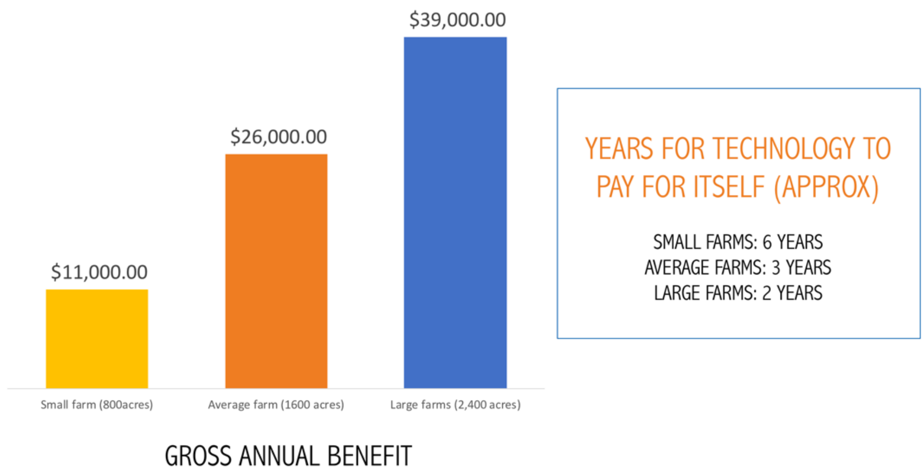


Figure 2: Types of Precision Agriculture

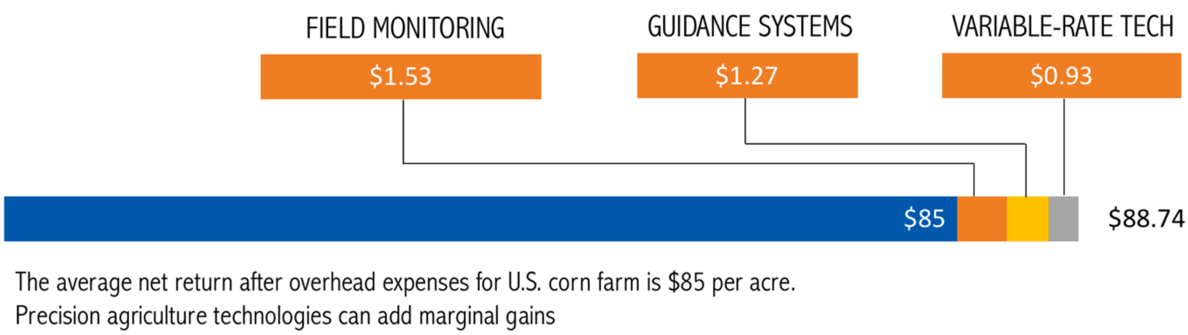
To adapt, large farms in urbanized cities have started to engage in modern farming method using sensors and informational technologies allowing these farms to experience higher yield through precision agriculture. However, **connectivity is not readily available in rural areas** attributing to the low crop yield they experience.

Precision agriculture, as shown in Figure 2, is a crop management concept that helps to increase productivity for farmers. It makes use of real-time information from sensors and geospatial techniques to allow better and more accurate decisions to be made [5].



Source: National Geographic

Figure 3: Years for Technology to Pay for Itself



Source: National Geographic

Figure 4: Returns Per Acre

Precision agriculture allow farmers to employ technologies to increase efficiencies and reduce wastage of resources. For example, farmers can make use of drones for monitoring and watering of crops to save time and increase precision. These technologies has the potential to pay for itself in less than 7 years and the returns can be as high as $39,000 USD per annum in large farms as shown in Figure 3. In addition, it has the capability to increase the average yield from $85 to $88.74 per acre for farmers as shown in Figure 4, allowing farmers to reap higher marginal gains with lesser resources. Farmers will then be able to enjoy greater efficiencies through precision agriculture tools without the worry of losing their capital fund.

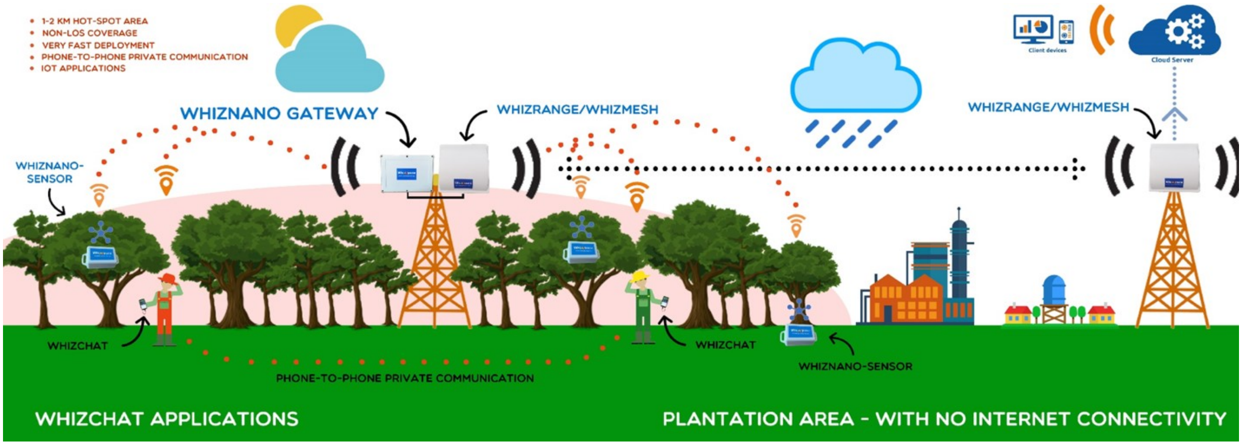


Figure 5: TVWS application

However, precision agriculture can only be made possible with the presences of connectivity to store, transmit and send data. Thus, in order for the farms in rural areas to produce comparable yield as their urban counterparts, connectivity is vital. TVWS helps to create a level playing field by providing connectivity to the rural regions to employ agricultural technologies.

Figure 5 shows the working of our TVWS products in a farm, WhizNano Gateway and WhizRange or WhizMesh is able to collect the information from WhizNano and sending these information to the cloud server towards the client devices. The reasons why TVWS is of preferential over other broadband and IoT solutions in rural agricultural area are explained in the following chapters.

3.0 WHAT IS TV WHITE SPACE

As the demand for wireless data connectively increase exponentially, many cellular operators are predicting a “spectrum crunch”, an insufficiency of radio spectrum. Hence, in order to increase capacity whilst maintaining the sparse architecture, it will require increasing large quantities of spectrum. This, however, might bring about concentration of spectrum and the relatively inefficient use that follows. Policy makers and regulators should henceforth increase the use of dynamic spectrum sharing and make licence-exempt spectrum widely available. [16]

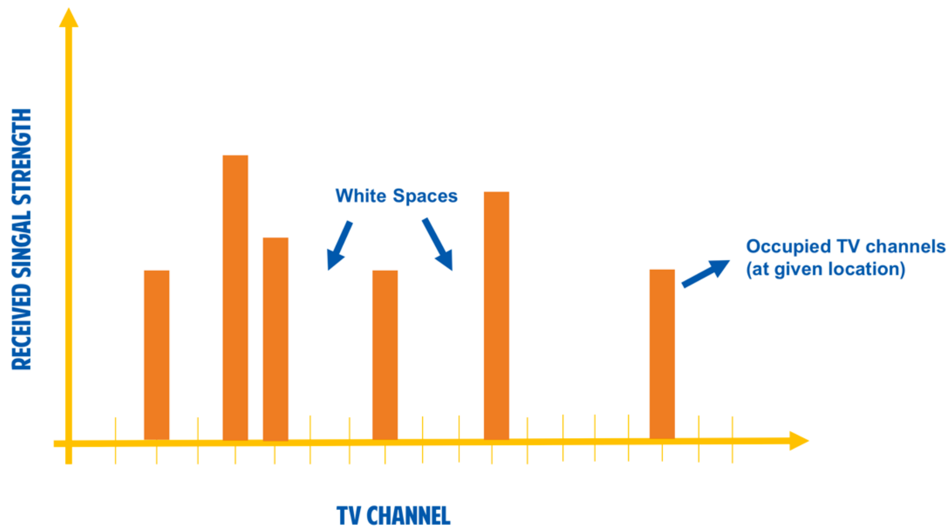


Figure 10: Concept of White Spaces

Dynamic Spectrum Access uses location-aware devices and online databases to provide low-cost broadband access and other forms of connectivity to consumers. In almost every part of the world, there are many TV broadcast channels that are unused – these empty channels (blocks of spectrum) are known as "white spaces", as shown in Figure 3. Dynamic Spectrum Access will be the first to be used in the TV-band White Spaces to deliver what is known as "Super Wi-Fi". Super Wi-Fi is similar to the existing license-exempt technology Wi-Fi, but better.

Most commonly, white spaces technology employs on-the-fly geolocation to determine to check channels availability wherever applicable devices are located. Devices will determine their location and query a geolocation database. The devices are not allowed to transmit until they have successfully determined from the database which frequencies, if any, they are able to transmit on their location. Then, the database will the TV white space channels, and at what power level it is permitted to operate on in its current location. This database will also have a list of all other protected TV stations and frequencies across the country, avoiding inference to TV broadcasts and wireless microphone signals.

Alternatively, the system is able to adopt real time scanning feature that is on top of the geolocation database, allowing TVWS to be implemented anywhere at any frequency band as long as the antenna frequency range is supported. This allow super Wi-Fi devices to switch from one group of channels to another. Translating to greater network capacity, greater number of users in a given area while at the same time protecting television reception from interference.

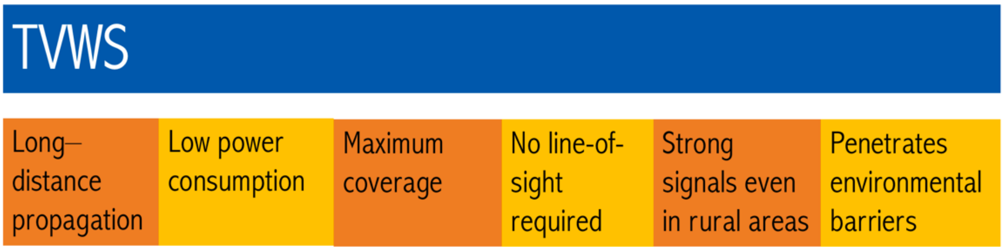


Figure 11: Features of TVWS

TVWS can penetrate through more obstacles as compared to typical Wi-Fi signal. This is due to the propagation characteristics of sub-1GHz spectrum, which allows for excellent coverage and better penetration through obstructions. Existing licence-exempt spectrum is located at higher frequencies which often have poor propagation characteristics as they are easily blocked by obstruction such as walls and foliage. This limits the ability of traditional licence-exempt technologies to provide in many urban and rural areas with large geographical area and blockages. Full features of TVWS can be seen in Figure 11. [16]

A strong Wi-Fi signal can cover 100 meters while a Super Wi-Fi signal at the same power level can easily travel 4 times the distance of a strong Wi-Fi signal. This leads to 16 times the area covered, resulting a lower network costs, lower power consumption and more bandwidth.

Table 1: Reduction in expenditure through TVWS

Reduced CAPEX	Reduced OPEX
• Longer range → Lesser Concentrators • Able to penetrate walls → Lesser Repeaters • Variable data rates → Easy deployment in different environments • Support large number of nodes → Lesser Concentrators • High data rates up to 54 Mbps → Future proof • Cable free deployment → Eliminates trenching	• License Exempt → No recurring costs • Point-to-Multipoint architecture → Ease of maintenance

As shown in Table 1, Super Wi-Fi has the capability to reduce overall expenditures through CAPEX and OPEX due to the advantages that TVWS carries. Hence, with TVWS, farmers will not need to worry the high-cost of deploying connectivity in their agricultural areas. Equipped with the ability to travel longer range and penetrate through obstacles also make TVWS an excellent candidate for the large rural agriculture areas with environmental obstacles.

3.1 COMPARISON TO BROADBAND SERVICES

Since TVWS leverage on empty channels in TV broadcast channels, there might be a growing concern of unsustainability since radio spectrum might be “used up”. However, most major European countries, South Africa, India as well as our ASEAN neighbour have already chosen to adopt the DVB-T2 standard. Hence, as more countries move from analogue to digital television, it will free up more TV frequencies, thereby, increasing the available TV white spaces to be used. Thus, this digital switchover will generate opportunity for empowering rural areas.

Broadband provides high-speed internet access and able to support applications such as web-browsing, video services IP TV, and so forth. [6] Common broadband transmission technologies can be seen in Figure 2.

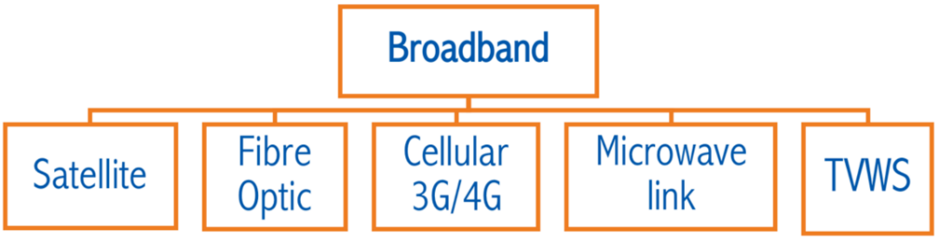


Figure 6: Common types of broadband services

Satellite network is able to cover wide geographical areas and interconnect remote terrestrial network. However, it requires high operating expenditure, the monthly recurring cost can be up to $1,000 USD and might not be the best option for rural areas with lower purchasing power.

Some would then suggest employing alternative network solution such as the conventional network like cable-laying network. However, cabling is expensive to lay in rural areas with low population density and they do not provide high coverage as its speed degrade as the distance increase. [7] This is more so as most agricultural areas span over very large areas which would renders fibre optic network ineffective.

Internet access (3G/4G) provides amazing speed with high bandwidth leading to much faster data transfer speed especially for network devices like laptop and mobile devices. However, this service offered by mobile operations is usually very costly as there is a lack of infrastructure in these remote areas. Thus, this solution is also not feasible for large scale farm. TVWS technology is able to perform 8 times better in terms of power consumption, 3 times in terms of exposure, with a cost of only one seventh of that of LTE [8].

Microwave link provides high bandwidth with no cables needed, it broadcast signals through radio using a progression of microwave towers. It is a form of line of sight communication as it requires obstruction less transmission between the receiving and transmitting towers for signals to be communicated properly at both ends [9]. Thus, if the line of sight is disrupted by obstacles such as buildings, the microwave communication will be disrupted as well. In addition, setting up the towers for microwave link requires high capital funding, building on the space of approximately 1 feet will require approximately $1,000 USD.

Lastly and most importantly, we have our TVWS products, WhizRange and WhizMesh. WhizRange provides long range connectivity up to 10km along with either a built-in antenna or external antenna. There is no need for line-of-sight thus even with the presences of obstacles, the connectivity will not be disrupted. On the other hand, WhizMesh provides connectivity up to a range of 5km with also either a built-in antenna or external antenna. This product support mesh topology where which device is able to connect each other, allowing the handling of high amounts of traffic as multiple devices can transmit data simultaneously. Therefore, WhizRange and WhizMesh will be the ultimate solution for farmers as it provides high coverage and efficient connectivity at low-cost.

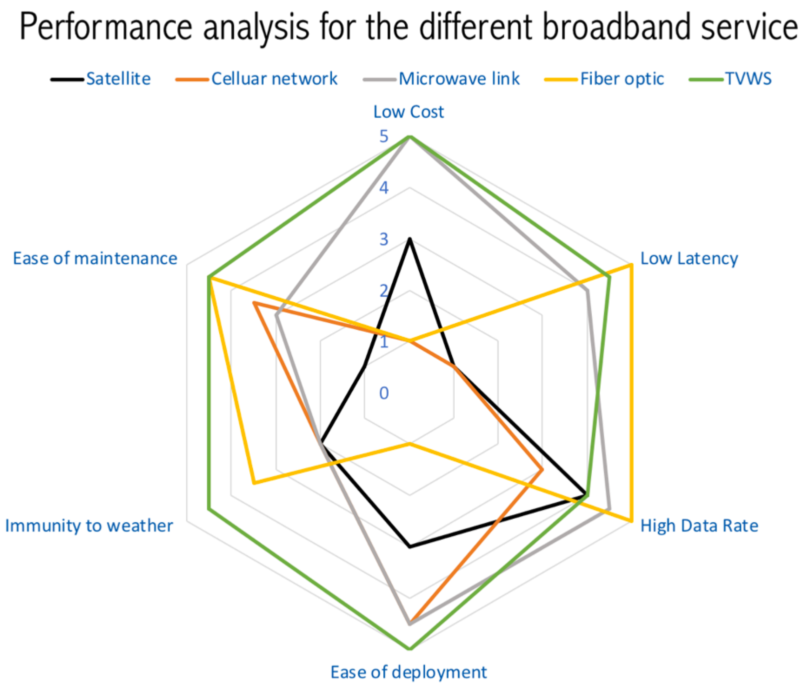


Figure 7: Performance Analysis For The Different Broadband Service

As shown in Figure 3, although TVWS data rate performance is lower than fibre optic and microwave link, overall it is still more cost-effective and provide several prominent advantages such as higher immunity to bad weather condition, lower deployment time and ease of maintenance.

TVWS requires low CAPEX and allow end users to enjoy zero recurring cost unlike cellular 4G and 3G, which increases it's affordability to end users in rural areas. Long distance reach of WhizRange and WhizMesh allow a smaller number of base stations to cover such user as compared to shorter range technologies like Cellular 3G/4G. Thus, it is estimated that the this technology will incur only one-tenth the cost of deployment. Furthermore, WhizRange and WhizMesh can be easily powered by solar panels thus reducing its operating expenses as well [10].

3.2 COMPARISON OF IoT SOLUTIONS

According to International Energy Agency, there will be over 14 billion network-enabled devices. Internet-of-Things (IoT) allow for the constant tracking of objects and for our everything life to be filled with wireless devices to improve our standard of living. Alongside the increase in the numbers of devices in the IoT space, there is a need to create new wireless technologies which is capable of supporting them [11].

Last-mile telecommunication networks play a vital role in connecting rural areas to the cloud. Therefore, revolutionary technologies need to be robust, flexible, scalable, affordable and user friendly to be the next generation of last-mile rural telecommunication networks [12].

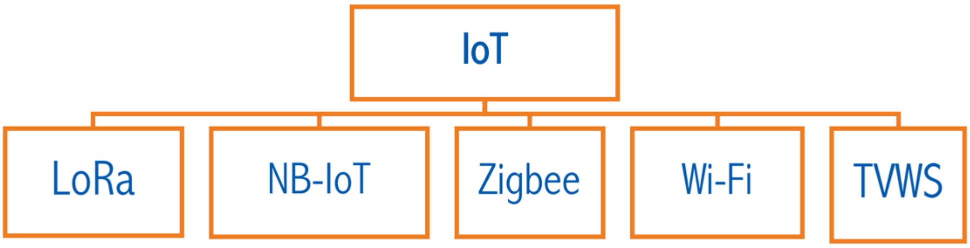


Figure 8: Examples of solutions for IoT

Some example of low-powered IoT solutions can be seen in Figure 8, such as LoRa, Zigbee, WiFi, NB-IoT and TVWS (WhizNano).

LoRa, and NarrowBand-Internet of Things (NB-IoT), the Low Power Wide Area (LPWA) technology with high coverage is developed to enable a wide range of new IoT devices and services [13]. It is the new transceiver types that target application where thousands of devices are used in large geographic area to collect sensor readings. Zigbee, however, only provide medium coverage which is insufficient for agriculture field despite the mesh network available.

Wi-Fi, or 802.11, is a wireless protocol aimed to provide off-the-shelf, easy to implement, easy to use short-range wireless connectivity with cross-vendor interoperability [14]. It is relatively inexpensive and readily available since no licence fees is required. However, Wi-Fi is not the best option for rural agriculture farms with large geographical areas and abundance of obstacles like foliage since the low coverage (usually 50 – 150 meters) provided by Wi-Fi is not large enough for farms that run on hundreds of hectares. Wi-Fi also has weaker penetration into dense substances such as buildings, trees and foliage as compared to Super Wi-Fi which is unsuitable for plantation areas with heavy foliage.

WhizNano is battery operated and capable of providing long range (up to 500m or 2km with higher-gain antenna). It has a low power and deep sleep mode while allowing a **data rate up to 250kbps** for large IoT networks and phone to phone communication. It is widely affordable and able support thousands of connections with IoT applications without cellular infrastructure.

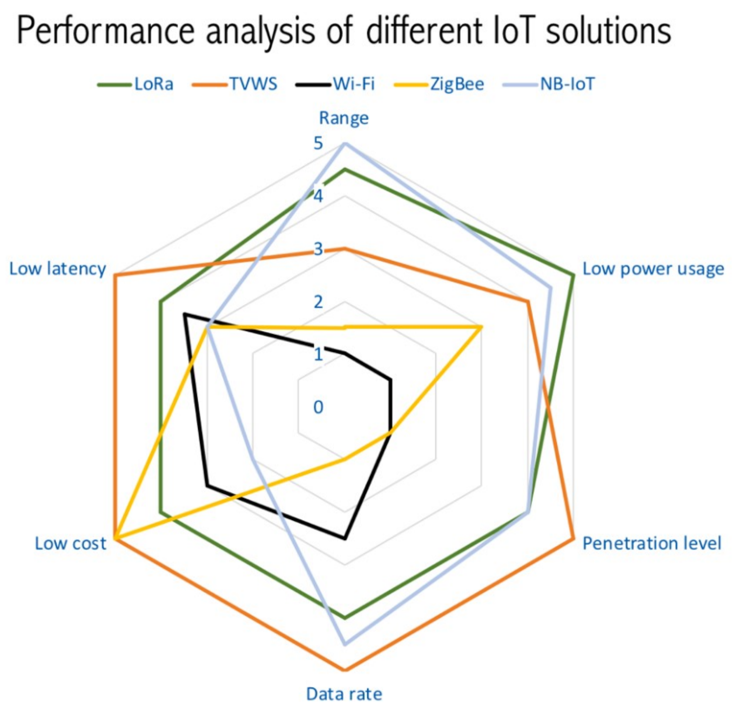


Figure 9: Performance Analysis of Different IoT Solutions

WhizNano wirelessly transmission of sensor information directly to the cloud. It has high penetration level, data rate, cost effectiveness and lowest latency amongst the 5 IoT solutions. This allows WhizNano is an excellent candidate for the IoT application in rural areas as the network is reliable and affordable. Furthermore, due to its ability to penetrate through obstacles such as foliage and trees, WhizNano is able to perform well in agriculture areas with an abundance of plantations or vegetations compared to its counterparts.

Notably, LPWA networks like LoRa and NB-IoT does not scale well, leading to congestion and inefficiencies. For example, using LoRa with static setting and a single sink as typically developed in their LoRaWAN has proved to be low in scalability [15].

4.0 APPLICATIONS OF TVWS IN AGRICULTURE SECTOR

4.1 SMART IRRIGATION

Farmers will typically follow a stipulated schedule for watering each crop. However, due to the complexity of predicting weather condition, it may easily lead to over or under irrigation causing the plant to die out. This also causes a waste of precious resources such as fertilizer, labor hours and water.

Smart irrigation solves the problem by relying on sensor and data transmission method to inform the farmers on the crop's conditions such as moisture and humidity levels. This can be done with the presences of TVWS broadband along with our WhizNano attached with the sensors to transmit the data to the farmer. Therefore, farmers will be able to water the crops with the right amount of water and at the right time to prevent wastage.

Through the usage of smart irrigation and proper use of fertilizers, there is 45% to 70% possible increase in crop yield [17]. Furthermore, water savings from switching to smart irrigation range from 30 percent in areas with more rain to more than 60 percent in drier areas. In a sample of 100,000-square-foot building, this would translate to cost savings between $4,500 and $8,500 annually. In combination with a drip watering system, the savings could reach 75 percent, or $11,000 per year [18].

4.2 AGRICULTURAL DRONES

According to Global Market Insights, agriculture drones will be valued at $1 billion by 2024. These drones require a very modest capital investment compared to most farming equipment and they are relatively easy to operate and it is safe and reliable.

There are several ways drones can be used for agriculture. For example, drones equipped with near infrared camera sensors will allow the drone to see the spectrum of light that plants use to absorb light for photosynthesis. This information along with the normalized difference vegetation index (NDVI) will allow farmers to understand their plant's condition effortlessly. In addition, some of the existing agricultural drones are able carry large amount of liquid and provide crop spraying safely at a fraction of the cost compared to a crop dusters. As for livestock farming, drones with thermal imaging cameras allow a single remote pilot in command to monitor livestock [19]. In this way, farmers can make use of drones to easily monitor their crops and livestock which is previously impossible. This allows them to gain in-depth analysis of their crops and livestock and carry out appropriate measures required. Hence, this reduces resources wastage and allow healthier crops and livestock to be grown.

According to Agribotix, an agricultural intelligence company, some of their customers who employed drones in agriculture field are enjoying $15/acre return on investment. For higher value crops that are vulnerable to diseases, such as potatoes, citrus, almonds and bananas, the financial benefit could be significantly higher as there is better monitoring through the usage of drones to provide sensor images [20].

Both of the two examples discussed will require TVWS application in order to be of value to the farmers. TVWS will be able to provide broadband services as well as acting as a data transmitter. The availability of connectivity also allows farmers to send their data collected by the sensors to the nearest laboratory for a more accurate analyzation of their crops and livestock.

Other applications possible include truck tracking and monitoring, perimeter monitoring and surveillance, crop parameters (fertilizer, moisture, temperature, water level, etc.) monitoring and office management.

5.0 SUCCESS STORIES

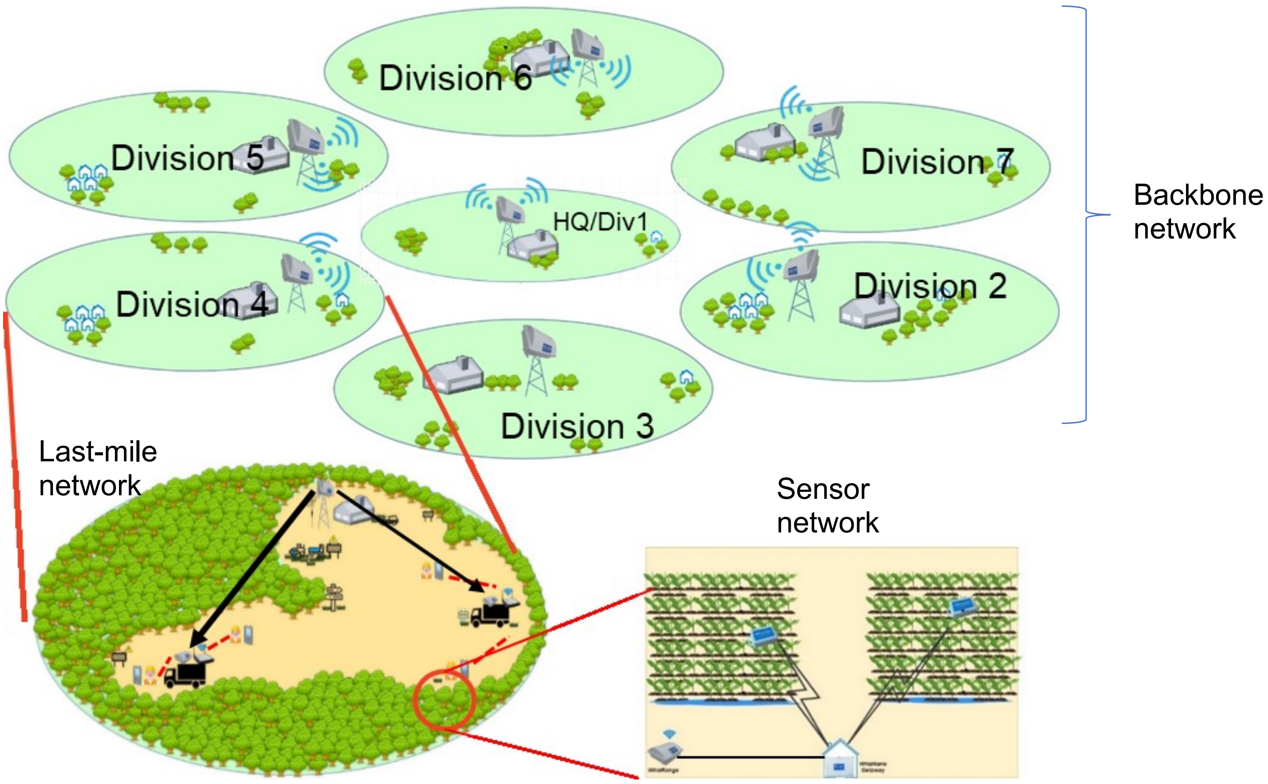


Figure 10: 3-layer of networks in plantations

After discussing with many plantation players, we realized that there are 3 layers of networks required in plantations as depicted in Figure 10. The backbone layer takes care of the coverage within the plantation that spans across different divisions. This is the basic infrastructure required to link up different divisions to the plantation HQ. Often this is served via satellite where signals from one division have to be sent across through satellite before arriving at the HQ resulting in significant latencies besides low data rates that only allows limited applications.

The second layer of network required is the last-mile network. The last-mile network connects key assets and people in the plantation such as trucks, fire engine, cameras, supervisors, workers, fire fighters, etc. Often the last-mile network just needs to be connected to the nearest division office.

The last layer is sensor network where low data rate sensors are deployed to collect ground data 24 x 7 such as moisturizer, water level, temperature, fertilizer, humidity, etc. The requirement of the sensor network layer is the communication modules have to be low cost, small form factor and can be battery-operated with long battery life.

Backbone Network in Sumatera, Indonesia

Whizpace is chosen to provide TVWS backbone network for the plantation. This plantation is around 5,000 hectares where only the HQ has internet access. We helped to connect up divisions to the HQ and deployed cameras and Wi-Fi access points to allow monitoring of work activities as we as basic internet access.

Currently, this plantation has connectivity with stationary LOS links using microwave links. However, some of the locations are blocked by foliage which the existing microwave link could not provide any connectivity. With Whizpace's TVWS solutions, divisions 10km away that are partially blocked by foliage and facilities totally blocked by thick foliage are able to get connectivity successfully.

The measurement results show that the connectivity is proven to be stable despite being blocked by foliage. It is also able to stream video link over TVWS which were very clear without pixelization. With TVWS, the plantation could stream HD video from 10km away to their main office for monitoring. With this large pipe, many sensors can be connected for enabling smart plantation and increasing productivity. For areas where there is no power supply, solar power and batteries are used to power the low-power TVWS equipment to provide seamless connectivity day and night.

Figure 11 shows some pictures of the actual deployment. As can be seen, the terrain is challenging with blockage and some nodes are powered by solar and battery.

In short, TVWS is able to provide reliable connectivity to rural agriculture area. This allow smoother communication in the plantation, thus greatly improve productivity. In addition, with the availability of TVWS broadband, plantations can now engage in precision agriculture by employing productivity improving technologies such as smart irrigation and drones through our TVWS products.

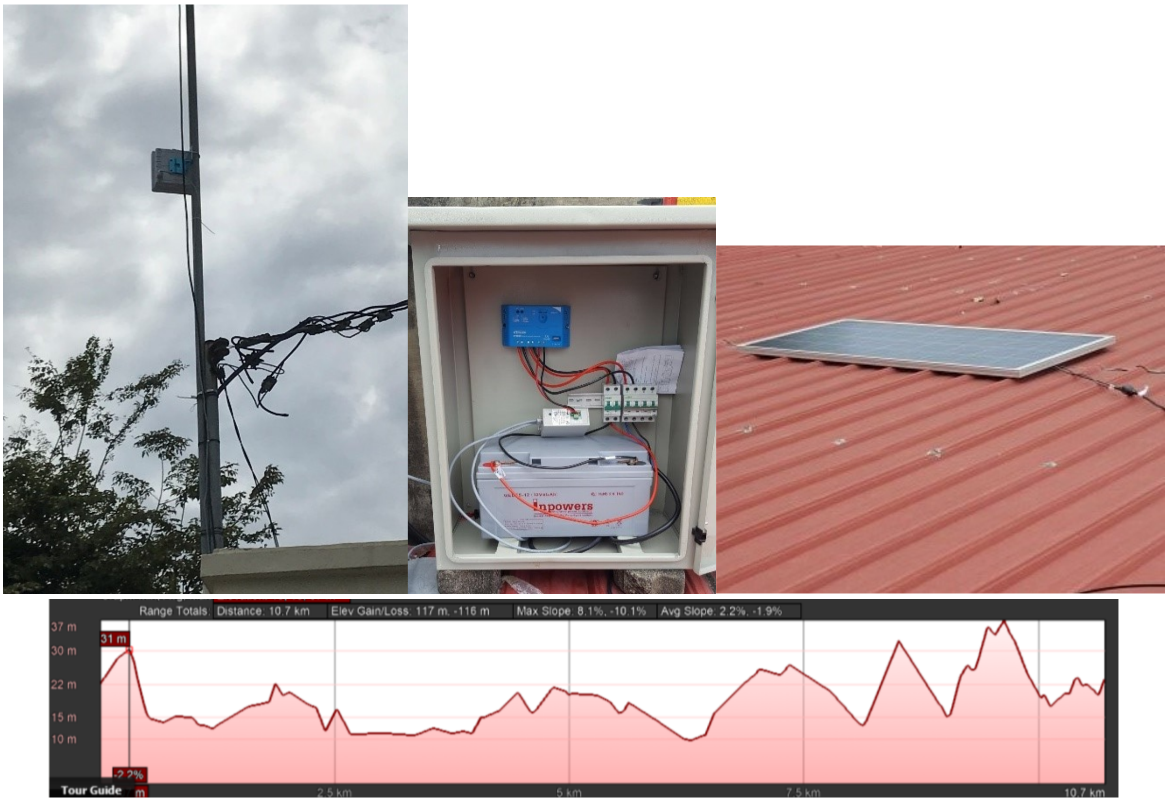


Figure 11: Deployment in plantation

Last-Mile Network in Sumatra, Indonesia

This customer is interested with the backbone network that we deployed above. They would like to have the same network in their plantation but extend the network beyond backbone to the last-mile as shown in Fig. 12. In this deployment, we setup the backbone network and the last-mile network successfully as can be seen in Fig. 13.

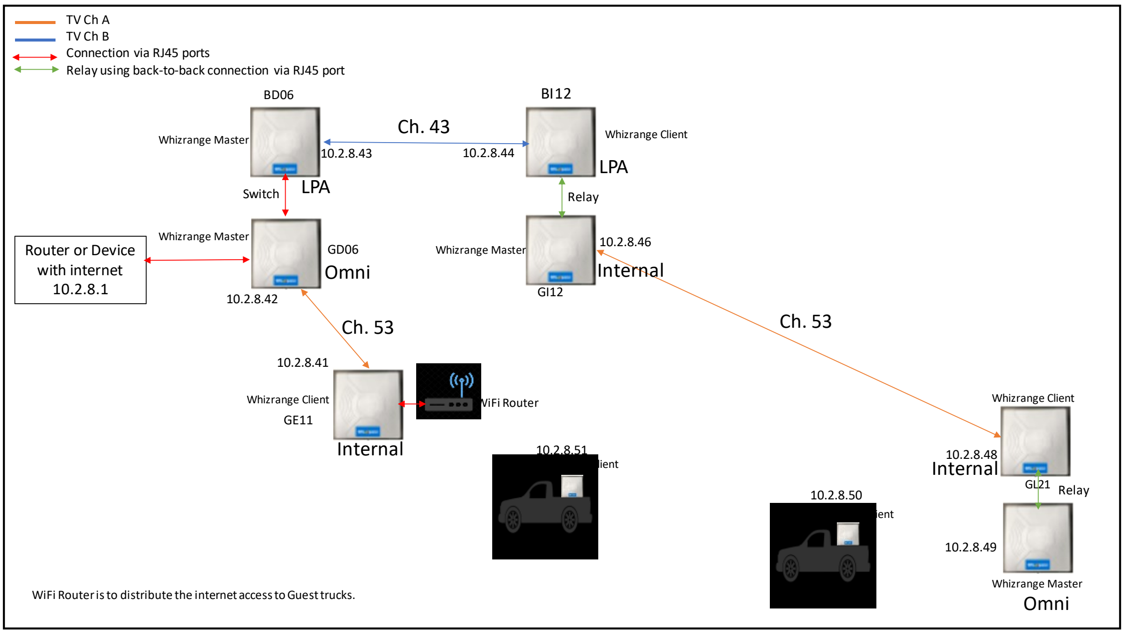


Figure 12: Last-mile network deployment

Figure 13: Whizpace devices installed as backbone and last-mile networks

With this successful extension to last-mile network, many things previously challenging are now possible such as tracking of trucks, coordination of harvest, tracking of workers, fire engine, fire fighters, etc. Figure 14 illustrates some potential applications in plantations when the last-mile network is setup.

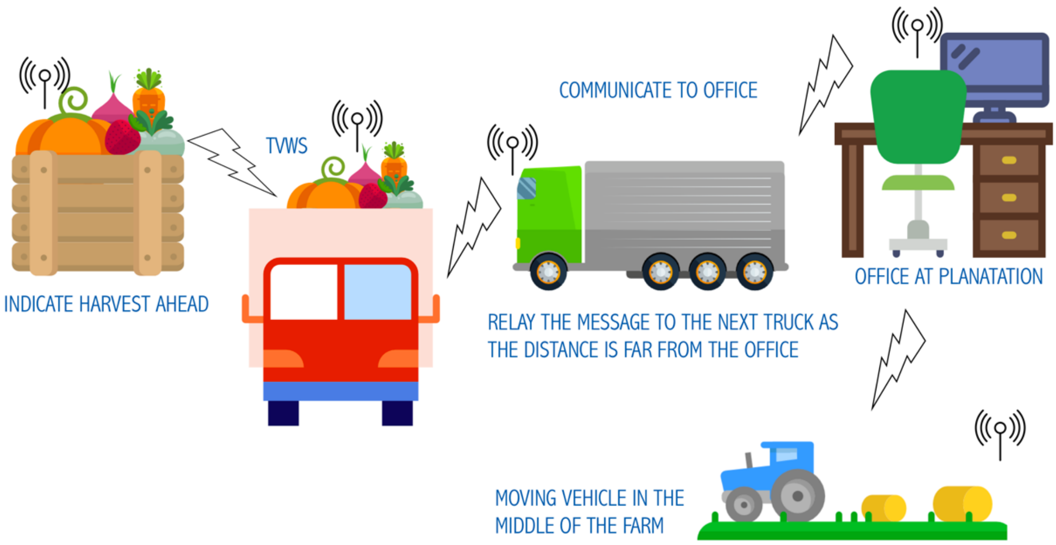


Figure 14: Applications enabled by TVWS

Sensor Network in Singapore

The last layer of network is the sensor network layer. In Singapore, the backbone network and last-mile networks are well covered. Plantations just need the sensor network to be enabled. In this plantation, we adopted our WhizNano solution to provide low-power, low cost option to enable sensor readings from the ground. Fig. 15 shows sensor deployments with our devices and the cloud platform used to visualize the data. Although the gateway is put inside the office with total blockage to the sensors deployed in the farm land, the network link is still very stable and able to send back data to the office in real time. With this layer enable, true precision agriculture can be carried out where the use of materials to grow the plants can be truly optimized for yield and low cost.

Figure 15: Sensor reading and the cloud platform that visualize the sensor data

6.0 OTHER APPLICATIONS OF TVWS

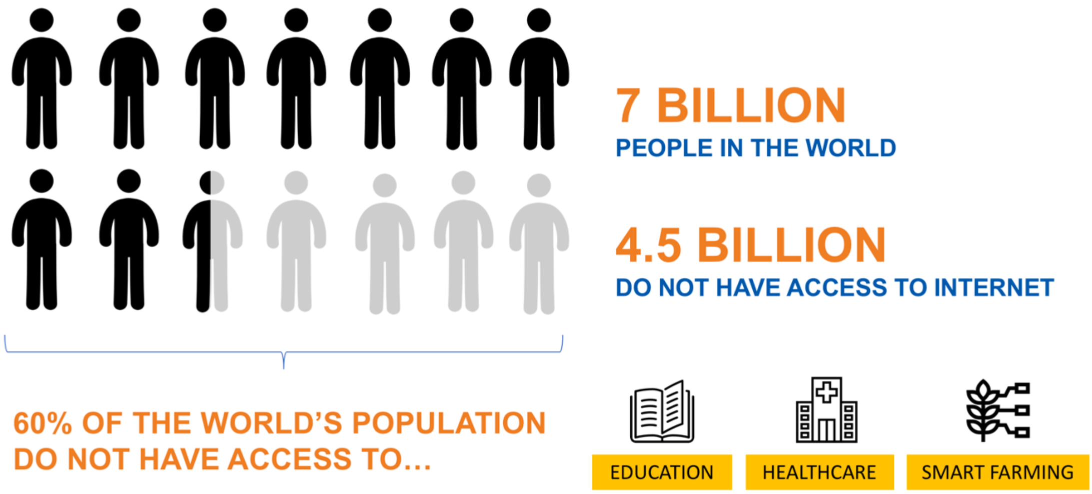


Figure 16: Demographics

Amongst the 7 billion people in the world, only 4.5 billion people have access to the internet. The remaining 60% of the people, however, are still suffering from the lack of internet connectivity. This barrier prevents the improvement in standard of living as the rich information on the internet is not accessed and productivity cannot be maximised.

TVWS carries the potential to provide internet connectivity to the rural areas where internet is the most inaccessible. Agricultural farms, hospitals and schools will then be able to enjoy better communication and increase in efficiencies since TVWS requires low-cost and low deployment time yet it is able to penetrate through obstacles and extend towards a longer range.

Fig. 17 illustrates various other applications possible besides agriculture. Our TVWS solutions have been adopted to provide internet to rural areas, enabling real-time video surveillance, monitoring energy assets, linking up sensors and gateways in smart buildings and facility management, as backup link to fibre network and enabling operational technology (OT) network for factory to move towards Industry 4.0.

Figure 17: Applications of TVWS

7.0 CONCLUSION

In an era where technology has revolutionized and improved nearly every aspect of our lives and our reliance for internet increases, connectivity should be seen a basic human rights for everyone. Thus, we should embrace innovations that can support our agricultural industries by improving access to connectivity in rural communities. Agricultural sector is one of the most important sector to secure the global food chain and ensuring mankind's survival. By employing TVWS, it is able to increase productivity of farms in inaccessible regions by allowing the usage of high-tech gadgets like sensors and drones to further maximise crop yield to ensure that we will have enough food for the future population.

Having broadband service in agriculture intensive areas rural areas will be able to provide more jobs opportunities as production expands thus allowing the previously unemployed to earn an income. Furthermore, as efficiency increase due to more precision in farming, it allows farmers to cut cost and expand his earning capacity. This would, in the long run, help to propel greater development in these regions and improve standard of living.

Furthermore, there are other noticeable positive spill over effects such as reducing global warming reducing degradation of farmland. Agriculture sector has been one of the primary producers of Green House Gases (GHGs) and over the past 50 years, such GHGs emission have nearly doubled [4]. This way, it will lead to unpredictable climate changes which will in turn affect many food-production process and nature reserves. Hence, the idea of a more sustainable farming through precision agriculture will benefit the global climate condition by reducing unsustainable farming methods.

TVWS have endless possibilities from providing connectivity in agriculture sector to sectors like government, education and healthcare to improve quality of life. With proper policies and regulations, TVWS is able to have far-reaching benefits into our lives and the power to alleviate extreme poverty in rural areas. The potential of TVWS is only limited by our own imagination.

Whizpace… connecting without barriers

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