Connecting the Unconnected 10% of New Zealanders by 2025: Is a MahiTahi Approach Possible?

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***Abstract*—The New Zealand Government has set the goals of having 99% of Kiwis able to access broadband with peak speeds of at least 50 Megabits per second (Mbps) by 2025, and with the remaining 1% able to access broadband with rates of at least 10 Mbps. There is an interesting question to be raised: is it possible to achieve these goals earlier? Inspired by the United Nations' Sustainable Development Goals (SDGs), especially the SDG 17 of Partnerships for the goals, we propose bottom-up and top-down partnerships based on a sustainable research enlightened MahiTahi approach to pursue the New Zealand rural connectivity goals. In Maori, MahiTahi means "collaboration" which best represents the key design and implementation principles embedded into our approach. It aims to address the three dimensional challenges of rural connectivity including the collaboration among various network access technologies to advance geo-reachability; the collaboration among different stakeholders to optimize social and economic reachabilities, as well as the collaboration among national and international knowledge societies from multiple disciplines to maximize knowledge reachability. Rather than providing a final solution, this paper aims to inspire and invite wider discussions and dialogues to collaboratively seek out a timely holistic solution so as to assist the Government to achieve Her goals as earliest as possible.**

Keywords: Internet accessibility, Rural broadband connectivity, Sustainable development goals (SDGs), Partnerships for the goals, Universal access

I. Introduction

In 2015, the United Nations launched the Sustainable Development Goals (SDGs) initiative, with the goal of mobilizing global action to end poverty, to protect the planet, and to deliver prosperity for all humankind [1]. In this context, the Internet technology is one of world's most powerful engines for social and economic growth and needs to fulfill its potential to assist each nation to pursue those 17 Goals, as well as the Internet should be open, secure, trustworthy, and accessible to all. In addition, the universal access to the Internet is a key ingredient to the SDGs, through the targets of 9.c and 17.8, and as a crucial enabler of the other goals. Although Internet penetration rates are well above 80% in developed countries [2], the people living in rural and low-income areas generally face access problems due to the substandard or no connectivity. The telecommunication infrastructure rollouts typically focus initially on high density areas where an adequate Return on Investment (RoI) is guaranteed, and if there are no Government subsidies on offering low-income and rural areas could be left with the substandard or no infrastructure. The New Zealand Government has set ambitious goals for the telecommunications infrastructure rollouts that are planned to be completed by 2025.

This paper considers the current situations and the challenges of providing broadband connectivity in New Zealand's rural areas. Potential approaches that might be adopted are identified based on the New Zealand context, as well as the Government supported telecommunications infrastructure rollouts that are currently underway.

The rest of the paper is organized as follows: a review of the rural broadband connectivity situation is provided in Section II. Section III discusses the main challenges in providing rural broadband access in New Zealand. Section IV includes a state-of-the-art review of emerging technologies that might be used to address the rural broadband gap. We present the MahiTahi approach in Section V. Section VI concludes the paper and discusses future work.

II. BACKGROUND

A. New Zealand Broadband and mobile initiatives

The New Zealand Government launched the Ultra-Fast Broadband (UFB) initiative in 2009 with the aim of closing the digital divide. The UFB initiative is to rollout optical fiber infrastructure to deliver faster broadband access to 75% of the population by the end of 2019 [3]. In the rural areas outside the UFB coverage, the Government has commenced the Rural Broadband Initiative (RBI) that aims to provide high-speed broadband using wireless connections to priority users and communities (e.g., businesses, schools and health services). The UFB initiative target is to provide Internet access at 100 Mbps downstream and 20 Mbps upstream while the RBI target is to provide peak broadband speeds of at least 50 Mbps [3].

The UFB initiative is a public-private partnership (PPP) between the Government and four companies: Northpower covers the city of Whangarei; WEL Networks cover the cities of Hamilton, Tauranga, New Plymouth and Wanganui. Enable Services Limited covers the city of Christchurch and some surrounding towns and Chorus covers the remaining towns and cities. Understanding that the private sector would not invest in broadband infrastructure due to a range of factors, the government intervened in 2009 and asked potential partners to co-invest in the deployment of optical fiber infrastructure utilising a business model that contemplates the transfer of ownership and operations to the commercial sector eventually [4]. The government established Crown Fibre Holdings (CFH) to manage the UFB initiative with a capital investment of around NZ$1.5 billion. The PPP has several projects underway involving partners including Vodafone and Chorus [5] $430 million to improve connectivity in rural areas. The Mobile Black Spot Fund (MBSF), that is managed by CFH, is another initiative created by the Government to address connectivity gaps along main roads and in tourism locations.

B. Current Situations

The UFB and RBI initiatives are being undertaken in two phases (UFB-I and -II and RBI-I and -II). 73.8 % of the optical fiber infrastructure for UFB-I has been built and there are 367,788 users connected out of the 1,103,874 users able to connect (in 50 towns and cities). The project is intended to be completed by the end of 2019 when 75% of New Zealanders are able to connect. With a Government investment of $130 million, UFB-II is aimed to extend the optical fiber infrastructure to 190 towns and speed up the deployment of UFB nation-wide.Thus, by the end of 2022, 87% of NZ population should have access to the UFB infrastructure [6].

RBI-I, which was completed in June 2016, provides broadband to around 300,000 households and businesses. Under RBI-I, 387 cell sites have been upgraded and 154 cell sites have been built. 1242 FTTN (Fiber to the Node or Neighborhood) cabinets have been upgraded allowing around 110,000 households and businesses to be able to access new or enhanced fixed line broadband. The broadband speed range is from 5 Mbps to 100 Mbps, and the latter speeds can be achieved where 4G exists (around 400 cell sites) [7]. The RBI-II intends to extend the high-speed broadband access to over 74,000 households and businesses in rural New Zealand. The Government has allocated $270 million to both RBI-II and MBSF to improve rural broadband and to reduce mobile blackspots [8]. CFH is partnering with the Rural Connectivity Group (a new joint venture between Spark, Vodafone and 2 Degrees). CFH is also partnering with nine smaller regional wireless Internet companies. Fig. 1 shows the current broadband coverage.

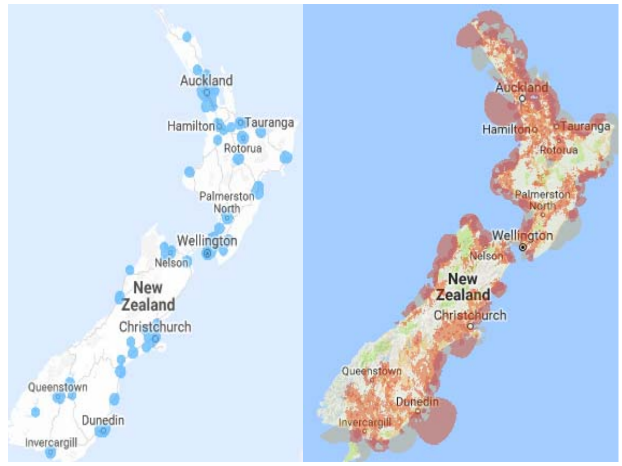

Fig. 1. Left: fiber coverage [9] and Right: rural broadband coverage [7]

III. CHALLENGES IN RURAL NEW ZEALAND

The main challenges for rural connectivity are discussed in the following sections.

A. Private/deregulated telecommunication market

The challenge with privatized or deregulated markets is that telecommunications infrastructure operators may not upgrade or invest in new infrastructure in areas where the adequate RoI is not guaranteed. The industrials expect Government to support infrastructure investment in loss-making areas. There is a strong and understandable role for Government to facilitate and intervene. In [10], the authors argued for a framework that meets New Zealanders' expectations by utilizing the five legislative or regulatory principles promoted by the government. The Government is continuing to react to rural telecommunications concerns and the RBI-II initiative has a set of investment and funding priorities that address under-serviced areas. The Government initiatives should contribute to the improved coverage in rural areas but it has issues that the initiatives are not able to, by themselves, achieve 100% coverage.

B. Digital divide

The digital divide is defined as the inequality among those who can access and use information and communication technologies (ICTs), such as the Internet. The high proportion of never-users and low-level users in rural areas shows that the digital divide persists in New Zealand and many people living in rural areas are digitally disadvantaged [11]. Although RBI has brought broadband connectivity to many rural areas, the skills and motivation are some of the factors for not using the Internet. Those challenges need to be addressed to ensure equal Internet access and basic use of information and communications technologies.

C. Topography of rural New Zealand

New Zealand consists of two main islands and many smaller islands around the coastline. The North Island has mountain ranges which form a spine with farmlands on both sides. Only a few mountains are higher than 2000 meters. While the South Island has more mountains with the highest peak in the 500 kilometer Southern Alps rising to over 3000 meters. The geography of the region imposes several challenges to the deployment of the broadband networks.

D. Rural Business Model

In rural areas, the necessity for better connectivity is driven by rural business needs rather than entrainment needs (i.e., one of the main connectivity factors in urban areas). It may be also noted that, most rural businesses are also homes.The ubiquitous high quality connectivity means the same experience in rural NZ as the urban NZ experience.

IV. Rural Access Technologies

Before discussing the rural access technologies, it is important to highlight the role of spectrum authorities (SAs) in regulating and managing access to this key national resource. Spectrum management is primordially justified because, as spectrum is assigned as a usage right over frequency ranges called bands, undesired spill-over signals from using the spectrum in one band may negatively impact the usage of spectrum in adjacent bands. Such a phenomenon is known as interference. Traditionally, avoiding or minimizing interference has been one of the main goals of spectrum management.Policy decisions that respond to the increasing pressure for competition in leading communication sectors such as cellular and wireless broadband services also demand spectrum management. It is clear that spectrum management needs to be adaptable to the emerging challenges.

Under a command-and-control regime, the SA determines the best use of the spectrum. When spectrum demand exceeds its availability, the SA faces a decision process: to whom to award exploitation of a particular band. As an example, to solve the assignment problem, the United States Federal Communications Committee (FCC) has adopted several practices including lotteries and administrative processes such as hearings to administer spectrum auctions. Currently most SAs use auctions to assign commercial bands. The following sub-sections include a discussion of selected rural access technologies, which can be used to share spectrum and expand coverage into rural areas.

A key aspect of the implementation of new technologies is the removal of Government regulations that may inhibit new approaches to the provision of telecommunications in rural areas. Opportunities for rural communities to rollout fibre or fixed wireless networks should not be limited by unnecessary Government intervention or by Telco's that have the rights to spectrum and infrastructure provision but have failed to provide adequate connectivity in rural areas. This is a "use it or lose it" principle.

A. 5G networks and D2D

The 5-th generation (5G) cellular technology is evolving and it is anticipated that 5G could become commercially available later this decade. It is a promising technology that is expected to provide increased throughput, lower latency, better coverage, higher spectral efficiency, improved flexibility and scalability, lower cost of infrastructure deployment, and improved reliability. 5G aims to utilize a range of technologies to capitalize the benefits of spectrum sharing and reuse. The current 5G architecture is "urban-oriented" [12] however, the researchers in [13], the reusability of network components, the exploitation of commodity hardware, and the deployment of solar powered energy-efficient devices, Unmanned Aerial Vehicles (UAVs), and advanced radio techniques. The authors have also proposed a 5G network for rural and low-income areas which meet those features.

Device-to-Device (D2D) communications allows two devices to communicate directly without traversing through a base station. It has been adopted as an optional feature in 3GPPP and LTE networks and is intended to be fully integrated in 5G networks. It aims to reduce the traffic load on transit points in a local area, such as a stadium, to support context aware, proximity-based services, or communications in natural disaster scenarios. The importance of D2D for 5G networks in rural areas has been recently outlined. Traffic offloading, lower cost of deployment, more favorable propagation conditions which allow less base stations within a given region are some of the main reasons to use D2D for mobile broadband access in rural areas. In particular, some applications that are well-supported by D2D, such as proximity-based services, take advantage of the location information of users, for public safety such as like police, fire prevention and ambulance services.

B. Wireless mesh/community network

It has been shown by researchers that the adoption of an indigenous bottom-up approach is the key to sustainable development [14]. Community networks follow the bottom-up philosophy and are "run by users, for the users". Community based resource pooling can be in the form of an extension of a user's paid service such as PAWS i.e.,pay it forward, where home users publicly share their home broadband connections. A cooperative wireless mesh network such as Guifi [15] is an open self-organizing community network that uses unlicensed wireless links and open optical fiber links. A mesh network is a network topology in which each node is capable of relaying data for others [16]. All mesh network nodes cooperate in the distribution of data throughout the network to the mutual benefit of its participants. With each participating node, the reachability, throughput and resilience of the network expands.

An ad-hoc mesh network allows public participants to join without prior authorization or setup. When powered on, the mesh network node scans the radio spectrum to identify other nodes it can connect to. Once connected, it benefits from the connectivity of others while also extending the reachability of the network for every other participant. With sufficient benefits to participation, an ad-hoc mesh network can quickly grow to provide shared connectivity on a global scale and at a much cheaper rate than a centralized topology.

The applications of community networking extend to much more than Internet access: for example, a number of community communication scenarios can be served such as local intranets and machine-to-machine networks that provide localized services, e.g., neighborhood groups and surveillance, high-speed peer-to-peer (P2P) networking and video conferencing, local TV/radio broadcasting stations. While community networking also has application in urban settings, the biggest draw for community networking is in rural settings (where cellular and satellite networks are expensive to install and operate). If suitably being incentivized such as using blockchain for building an economic substrate, community networking has the potential to mitigate the digital exclusion of rural populations by breaking the impasse emerging from the mismatch between the economic (profit seeking) interests of commercial service providers and the egalitarian global access to the Internet for all (GAIA).

In the developing world, banking is often non-existent or highly inefficient. The popularity of mobile banking has shown the need of this niche in the developing regions (and in Africa, in particular). Furthermore, there are innovations such as the smart currency disruptive technology using decentralized, highly secure cryptocurrencies that allows for secure and direct digital transfer of values and assets without any intermediate entity such as individual/bank/government, which promises to provide further value-added services to the developing regions.

Using Blockchain, we can open up access to privately owned Wi-Fi networks in a way that is appealing to both consumers and providers; for example, Wi-Fi owners may have an incentive to open up their networks to customers making micro-payments through a cryptocurrency system. In that respect, it has been documented by firms such as Cisco that Wi-Fi (commercial options such as 4G) is the predominant access technology that mobile devices use to connect to the Internet.

The appeal of cryptocurrencies is that it can facilitate micropayment without any middleman surcharge that traditional payment services suffer from. The uptake of this technology can create an evolved form of wireless access services distinct from the traditional Internet services offered by ISPs.

C. TV White space

TV-White space (TVWS) is the unused spectrum or portions of spectrum found in a typical terrestrial television broadcast system and the unused capacity could be used to complement wireless communication in rural and isolated areas. Terrestrial television broadcasting typically uses low frequency bands that travel longer distances than the higher frequency bands used by the current generation wireless technologies and the next generation 5G technologies.

The TVWS technology utilizes the spectrum in the UHF band that has been released by the transition from analog to digital television and new techniques to access underutilized spectrum within the digital television spectrum bands. This spectrum, referred to as "white space" is a great opportunity as: (i) it is regulated to operate free of charge; (ii) it can achieve longer ranges and is endowed with good penetration characteristics compared to the higher frequency spectrum planned for urban 5G implementations; (iii) it has been found in sufficient quantities in well-developed locations worldwide [17] and (iv) it is expected to be found in much higher quantities in the rural areas of the developing world which are usually poorly covered by television broadcasters. TVWS can play the role of spectrum of choice for either the community mesh networks built around the world or for backhauling mesh network traffic to a fiber access point as recently tested in India [21]. Besides its application to the rural areas, it is also envisaged that TVWS could be used in the next generation 5G networks to support bandwidth frugal carrier applications with long range access constraints

We can extend the Integrated Communication and Broadcasting Network (ICBN) concept to build up the heterogonous network with better coverage and low-cost [18]. The idea is to consider the convergence between broadcasting networks (using TVWS) as downlink (for content pushing which may not be very time sensitive) and mobile telecommunication networks (e.g., 5G) as downlink/uplink for time-critical services. The key issue is the service aggregation and handover among the different networks/base stations to deliver services with a consistent level of quality for the rich media applications across mixed broadcast networks.

D. Airborne networking

Since there is no single one-size-fits-all solution that can efficiently meet all of the needs of universal service provisioning, global wireless coverage will likely require the interworking of multiple heterogeneous wireless technologies. In the areas where providing a terrestrial backhaul solution is difficult or cost-ineffective, aerial platforms (including satellites, solar planes and drones, balloons and so on) can provide a viable alternative. The most traditional aerial networking solution is to use satellites, which come in different varieties, including: (1) geostationary (GEO) satellites; (2) medium-earth orbit (MEO) satellites; and (3) low-earth orbit (LEO) satellites. Other aerial networking technologies, such as small UAV drones, balloons, low-altitude platforms (LAPs) and higher-altitude platforms (HAPs), are emerging as novel solutions for rural areas and it is expected that these technologies will complement and augment existing terrestrial and satellite wireless technologies.

The promise of aerial networking for GAIA can be gauged from the research being undertaken by the Internet giants Google and Facebook, who are active in their efforts to bring the Internet to the billions of people with poor or no Internet connectivity due to the digital divide. Google on their part launched "Project Loon" in 2011 as a moonshot aiming at bringing ubiquitous Internet access to everyone through the use of aerial balloons flying at an elevation of around 20 km. While Facebook is trying its hand with the Aquila solar power drone as part of its Internet.org project. It is designed to use free-space optimal communication (FSO) with high-speed lasers as the technology of their choice. As can be expected, these technologies have their own bandwidth, latency, price and performance tradeoffs, which are explored in more depths in [19], [20].

V. The MahiTahi Approach

The Government initiatives to provide broadband connectivity in both rural and urban areas have largely been top down. In particular, rural New Zealanders could be more active and being engaged in the project. According to most participants of the Rural Connectivity Symposium, the reality of New Zealand rural connectivity is different from what the RBI-I progress report showed and there is a lack of knowledge about what the available services are. They also mentioned that the new initiative is market driven instead of needs driven, and those real needs would not be addressed by the RBI-II project.

The Government approach to solve the connectivity problems in rural areas has barely considered the socio-technical needs of people living in rural New Zealand in any of the phases that compose the lifecycle of the rural connectivity service-design, development, preparation and delivery. However, it has been recognized that today's service should be people-centric and the quality of the service is determined by the efficacy and efficiency of the interactions between the customers and the provider (Government and private Telco's) to co-create value. Therefore, we propose a new approach to expand the rural connectivity to the remaining 10% of rural population, the bottom-up and top-down partnership based on a sustainable research enlighten (MahiTahi) approach.In Maori language, MahiTahi means collaboration. To create value, the different partners (e.g. Telcos), suppliers (e.g. WISPs), Government and rural New Zealanders work together to create best values. Information, material, resources and money should flow among all the participants of the network by using bottom-up, top-down and resource pooling (see Fig.2). Each partner contributes through the own core competencies and know how to benefit from the optimization of the whole network. The above mentioned challenges provide research opportunities. The researchers can work with other partners to solve underlying problems and goals for future development. Through the stable, well maintained and established relationships among the partners, the services can maintain itself [21].

We use Fig. 2 (below) to illustrate the major components of the architecture of the MahiTahi house-like approach. All of the components of the architecture are essential to support and optimize the collaborative approach. The goal of connecting the unconnected 10% of New Zealanders is supported by the collaboration among the partners as shown in Fig. 2. There are five main pillars in the house which are key dimensions of our system. The external and internal funding and scholarships to conduct research and development activities are intended to find connectivity solutions tailored to rural needs. The economic dimension supported by the public and private investment as detailed in Section II. The technical factors greatly influence the functionality and usage of the rural networks as well as the set of practices for operations and management. That is why we believe the knowledge societies such as academics and researchers can also play a critical role within these partnerships. Finally, the social dimension that recognizes the complex relationship between people and the system. The aforementioned technologies are the bricks and mortar which also support the connectivity goal. Fig. 3 illustrates the inter-relationships among the main service system resources and stakeholders for the proposed approach. For example, a family lives in a hard-to-reach rural area and runs a small agri-business. The family utilizes the Internet to run the online marketing and sales business, also for household activities such as banking and educating children. The family may find unsubsidized telecommunications and Internet services to their region are too expensive. They can talk to the rural communities who have a partnership with them then raise the request to a research and development agency to inquire a possible solution that is feasible for them. They are assisting the rural connectivity communities to define alternative connectivity service solutions tailored to their needs. After several meetings with the related communities, the family could be recommended on trying an aerial-based e.g., UAVs-assisted delay tolerant Internet solution to get access to the Internet during working hours. The

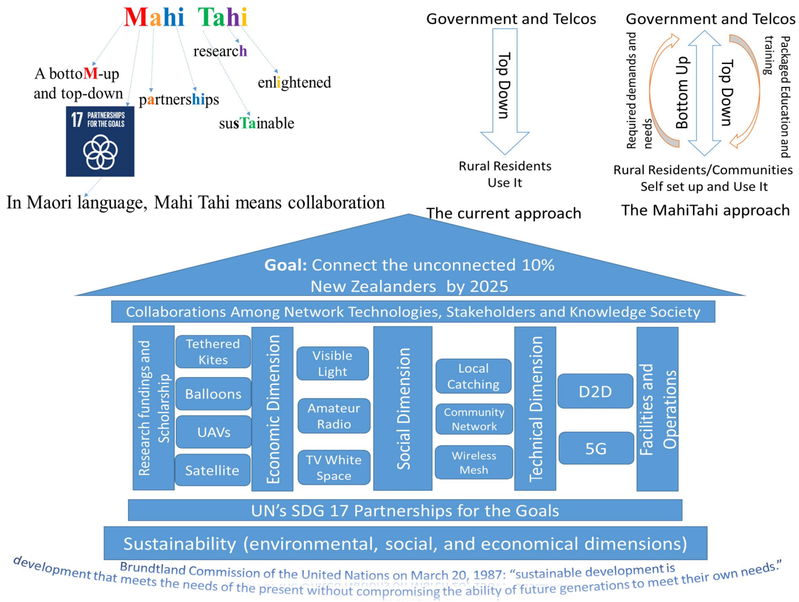

Fig. 2. The architecture of MahiTahi

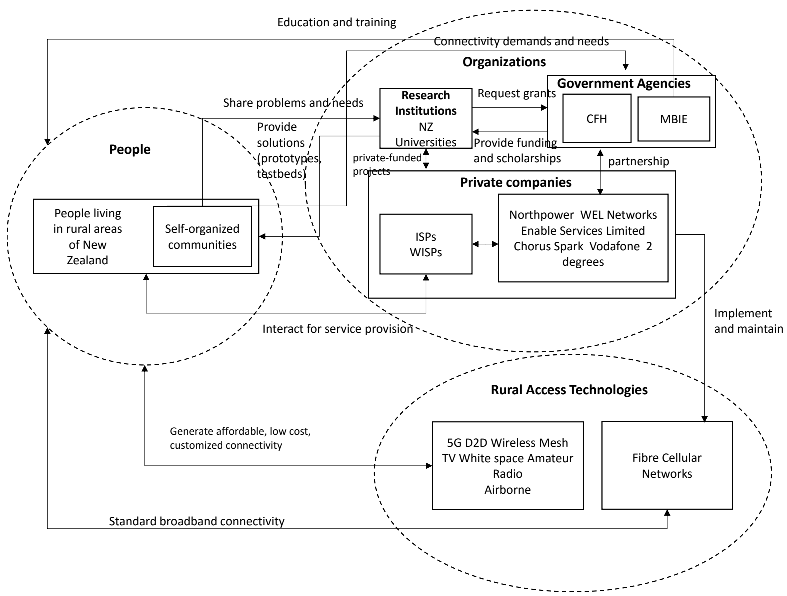

Fig. 3. MahiTahi as a Service System

Government and/or service providers could provide fundings and/or devices to the research and development agencies to develop the innovated solutions. Then the researchers can engage the end-users to set up the system, educate them to use and collect feedback for system betterment.

The New Zealand Government has used the PPP strategy to rollout rural broadband connectivity as it offers several benefits to both Government and private sectors, such as increasing private firms' profits, expanding public working space, boosting confidence and knowledge development [22]. The PPP strategy could dramatically reduce the cost to the Government for national infrastructure development. However, the PPP strategy is not an unimpeachable solution. Our review shows that there is a consensus among Government and private sectors about the need for more than one solution to provide ubiquitous broadband connectivity in rural New Zealand. Although RBI-I has been developed using a combination of fixed line devices and new towers, for RBI-II, "the Government did not specify a specific technology type. Regional operators were encouraged to participate in the tender process with innovative solutions.". In New Zealand Rural Connectivity Symposium, one of the participants mentioned: "One thing we should all acknowledge is that no one solution can do everything in rural areas. Rural New Zealand is very challenging and the key is picking the right recipe out of all these components to provide New Zealand with improved broadband." Some of the researchers mentioned that one key lesson learned from the Hurunui Kaikoura earthquake is that "network diversity into any area is a real benefit". Regional WISPs participating in RBI-II also expressed their opinions about they are offering several connectivity solutions tailored to people living in rural New Zealand.

VI. Conclusions

Considering the challenges of connecting the unconnected 10% of New Zealanders, the constrains of the PPPs, and the available broadband access technologies, we have proposed a MahiTahi collaborative approach that enables local connectivity first and then global communications by connecting people as fast as possible with a diverse range of strategies. This approach can be trialled in some areas of rural New Zealand, and adopted elsewhere as the approach and its implementation process are evaluated. In addition, our proposed solution still faces technical challenges, including the need for renewable power in those electricity-scarce areas. Additionally, there are challenges with hard-to-reach regions and the exorbitant cost of fixed Internet infrastructure in those places. This paper only initiates a proposal on how to extend broadband connectivity in rural areas using a collaborative approach. There are still several issues that need to be addressed in a more holistic manner including private/deregulated telecommunication markets, digital divide, the topographical barriers and rural business models.

We hope that this paper will inspire and motivate more interactive discussions among Government entities, Policy Makers, Telecommunications Infrastructure and Internet Service Providers. These discussions should also include Science, technical and other knowledge-based Societies so as to collaboratively seek an integrated and holistic solution to assist the Government to achieve National Goals and provide universal, affordable and broadband access to all New Zealanders as early as possible.

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