Connecting Makaraka - A Case Study to Provide Connectivity in the Rural Area of New Zealand

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Abstract. Broadband availability is an important asset for deriving change in the societal and economic development of a country. New Zealand's rural areas have limited broadband connectivity and there are some beautiful tourist destinations which do not have broadband availability on site. In this paper, we aim to provide a broadband connectivity model for basic and high speed data services for the area of Makaraka in the Gisborne region of New Zealand. The model proposes the placement of the access points, their channel selection scheme, transmit power requirements and appropriate installation height in detail for different frequency bands and data rate requirements. It is evident from the simulated results that outdoor area of Makaraka is able to get broadband connectivity which will help NZ to drive towards the theme of highly-connected society.

Keywords: Broadband communication · Internet · Data connectivity

1 Introduction

The ever-developing digital world is significantly affecting many aspects of New Zealanders and their lives. Information Communication Technology has become the vital part of the businesses, education sector and health care. In line with the ICT, there is an increasing usage of the broadband at every stage for example from basic data services (web and email) to high quality video streaming and gaming. Therefore, Government of New Zealand is aiming to provide broadband and cellular coverage to majority of the areas for making New Zealand a leading digital and highly connected nation. Rural areas of New Zealand have the low population density and network operators have not invested initially in providing broadband coverage to these areas. According to a study in [1], many of the rural areas of Australia and nearby countries also face the broadband un-availability and dis-connectivity issues.

Recently Ministry of Business, Innovation and Employment has initiated Rural Broadband Initiative to deliver better and improved wireless broadband services to the rural and urban areas of New Zealand. Several initiatives have been taken by the higher authorities for example Digital Economy, Mobile Black Spot fund, Ultra-fast Broadband Initiative and Rural Broadband Initiative to progress in the information and communication technology [2]. Availability of broadband connection may be useful in

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the foundation of many more applications other than Internet and data-browsing, for example Indoor Localization, health management and improved surveillance systems [3, 4]. The region of Gisborne comes in the plan to receive new Ultra-Fast Broadband, Rural Broadband and Mobile Blackspot programme coverage. However, there are some specific areas within the Gisborne region which need further detail and planning. Makaraka is a small area within Gisborne with very low population and doesn't have broadband connectivity across it. In this paper, we aim to propose an initial broadband design for Makaraka area in the Gisborne region to provide basic and high speed connectivity. We propose the coverage plan and design considerations to deploy the broadband network successfully within the region. We also provide the coverage map and limitations for two connectivity schemes that is basic and high speed connectivity under two different frequency considerations, 2.4 GHz and 5 GHz.

1.1 Background

The existing outdoor area of Makaraka has no broadband coverage and there is only one fiber optic cable line present at Makaraka School. There is a need to provide Wireless Internet coverage based on advanced technologies which should be aligned to standard Wi-Fi systems. There is a need for reliable and constant Internet connection while moving around the Makaraka central area. The broadband access system is expected to cover the outdoor area of Makaraka stretched over 3.7 $\times$ 3 km square area (approx.). However, because of the low population density at the borders of the area, this paper focuses on providing the coverage in the central densely populated area of Makaraka.

1.2 Objectives

The objectives of this paper is to provide a proposal for installing an outdoor Wi-Fi system for Makaraka area. The scope of the paper includes the planning and designing of the outdoor Wi-Fi Internet Access System for Makaraka. The equipment supply, delivery to site, installation, testing and commissioning of the outdoor Wi-Fi system for Makaraka area are out of scope of this paper. The ultimate goals for the project are to:

- Identify the best fit equipment for installing the outdoor Wi-Fi system for Makaraka area.
- Adopt the latest wireless standard of dual-band implementations (2.4 GHz and 5 GHz) with multiple-input and multiple-output (MIMO) technology.
- Provide better wireless performance, reliability and availability (a better user experience).

2 Network Design

We propose a wireless mesh network based design for providing broadband connectivity in the specified area of Makaraka. The two important design components of the network are Mesh Gateway and Mesh Nodes, explained below.

Mesh Nodes: Mesh Nodes are the access points responsible to provide Wi-Fi coverage to the users in the area and establish a wireless backhaul link to the backbone network. The primary focus of these nodes is to provide 802.11 access capabilities and forward the data of the users to and from the Internet. They also enforce Quality of Service rules for the data traffic and are the end points for the subscribers to get internet access.

Mesh Gateway: Mesh Gateway or root access point is responsible to forward the traffic between Mesh nodes and the central backhaul network at Makaraka School. A mesh gateway is responsible to handle the data from different mesh nodes. The nodes automatically select the shortest path to gateway based on the dedicated algorithm.

Figure 1 below shows the wireless mesh network model for the Makaraka Area, which involves a Mesh Gateway (Wireless Controller) and several Mesh Nodes (Wireless Mesh Access Points).

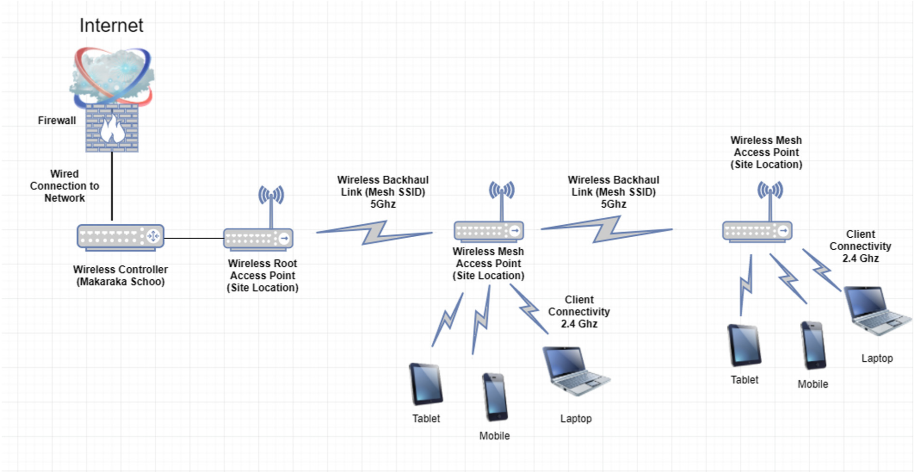

Fig. 1. Proposed network model

3 Design Considerations

Following are some important design considerations for the Wireless Network of Makaraka.

- Maximum number of client devices on each Access Point (AP): The number of clients connected to each access points may vary depending upon the type of application used by the clients and the type of the access point. For Basic Connectivity (includes Web, Email, Multimedia), it is recommended to have 40 to 60 users for a 2 × 2 MIMO AP and 60–80 users for a 3 × 3 MIMO AP.
- Transmission Power Level of each AP: 18 dBm.

- Channel Reuse Pattern: Fixed or Flexible (Channels should not overlap with neighboring AP).
- Received Signal Strength Indicator (RSSI) and Signal to Noise Ratio (SNR) for data Services: Minimum RSSI: −70 dBm, SNR: 20 dB or higher.
- Data + Multimedia: Minimum RSSI: −67 dBm, SNR of 23 dB or higher.

3.1 Wireless Mesh Access Points

We consider the network to be Wireless Mesh Network where APs communicate among themselves and back to root access point wirelessly over a radio backhaul. All APs in the network mesh have fixed configuration for the wireless mesh backhaul communication. We consider that APs should use a protocol to decide the best path through the other mesh APs to the main AP and also, AP should be dual-band (2.4 GHz and 5 GHz) with MIMO technology.

3.2 Wireless Root Controller

In our proposed design, all of the APs need to be connected to the central Wi-Fi controller wirelessly. The Wireless Root Controller is to be places in Makaraka School at a suitable location. We propose to connect Wi-Fi controller with the wired network for Internet connectivity and manage it centrally. The root AP connected to the controller is able to support all other mesh AP.

We consider to locate the Root Access Point on a tall building or tower at Makaraka School. However, the Mesh Access Point locations are short building tops or street poles. In our design, it is recommended to place AP at a distance between 200 m to 400 m if the backhaul mesh link is at 5 GHz. An outdoor AP may serve a client at a distance of 300 to 500 m. There should be maximum 3 to 4 hops between root AP and mesh AP. More hops can be supported but this is the recommended figure. Client are typically laptops, personal cell phones, or hand held devices.

4 Proposed Network Design

In this section, we explain the complete network design to provide basic or high speed connectivity in the Makaraka area based on dual frequency standards. The model has been proposed based on the simulation results of Aerohive online network development tool [5]. There can be modifications made to this design to provide better connectivity and reliability based on the number of users in the area. Table 1 highlights the access point locations for basic and high speed connectivity under 2.4 GHz frequency band. The expected data rate that can be achieved in the specified region which lies in the range of 78 Mbps to 174 Mbps for basic connectivity and 104 Mbps or more for high speed connectivity.

4.1 Basic Connectivity- 2.4 GHz

Figures 2 and 3 below show the received signal strength indicator (RSSI) Heat map when five access points are placed at the positions specified in Table 1. The channel selection is done manually by assigning non-over lapping channels to avoid interference.

Table 1. Access point locations (2.4 GHz)

Type of connectivity	Location of the access point	Channels assigned	Distance to neighboring AP (meters)
(Basic connectivity)	Makaraka school	11	440
	Rose land tavern	1	394
	AGRIplus	6	357
	Intersection of main road and Paker Ln	11	471
	Motor camp entrance (Gate 3)	1	
High speed connectivity	Makaraka school	6	352
	117 main road	11	326
	Makaraka veges	1	336
	67 main road	6	189
	Intersection of main road and Paker Ln	11	331
	35 main road	6	

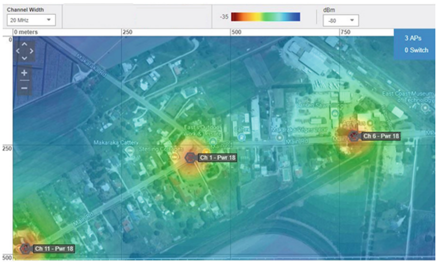

Fig. 2. RSSI heat map 1

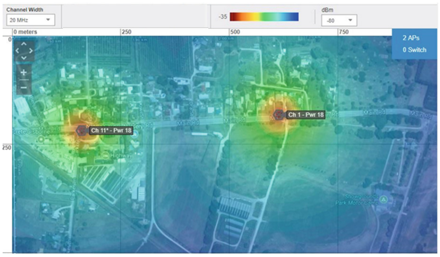

Fig. 3. RSSI heat map 2

4.2 High Speed Connectivity- 2.4 GHz

Figures 4 and 5 below show the RSSI Heat map when six access points are placed at the positions specified in Table 1 for high speed connectivity at 2.4 GHz band.

Table 2 highlights the access point locations for basic and high speed connectivity under 5 GHz frequency band.

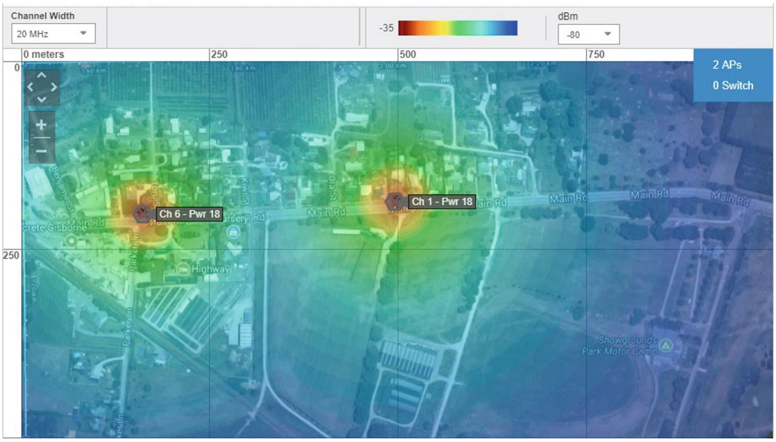

Fig. 4. High- speed connectivity (2.4 GHz) - RSSI heat map 1

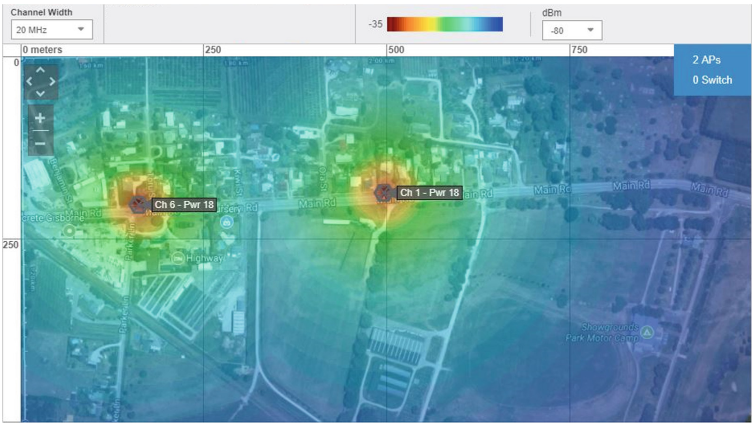

Fig. 5. High- speed connectivity (2.4 GHz) - RSSI heat map 2

Table 2. Access point locations (5 GHz)

Type of connectivity	Location of the access point	Channels assigned	Distance to neighboring AP (meters)
Basic connectivity	Makaraka school	112	338
	117 main road	108	376
	Makaraka veges	100	285
	67 main road	104	189
	Main/Paker Ints.	165	331
	35 main road	100	
High speed connectivity	Makaraka School	112	338
	117 main road	108	376
	Makaraka veges	100	285
	67 main road	104	189
	Main/Paker Ints.	165	331
	35 main road	100	

4.3 Basic Connectivity- 5 GHz

Figures 6 and 7 below show the RSSI Heat map when five access points are placed at the positions specified in Table 2.

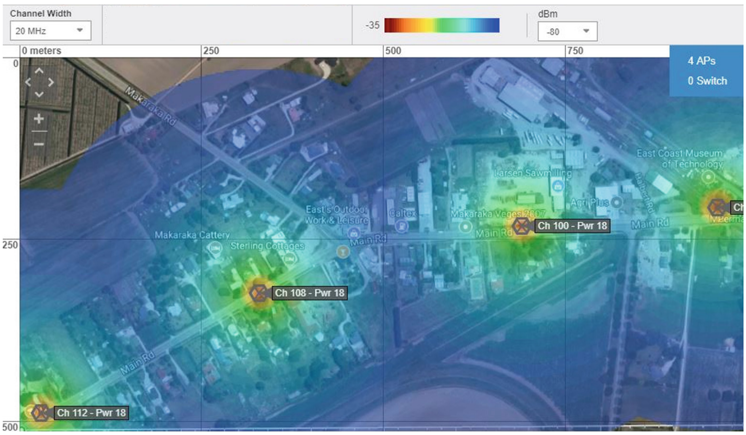

Fig. 6. Basic connectivity (5 GHz) - RSSI heat map 1

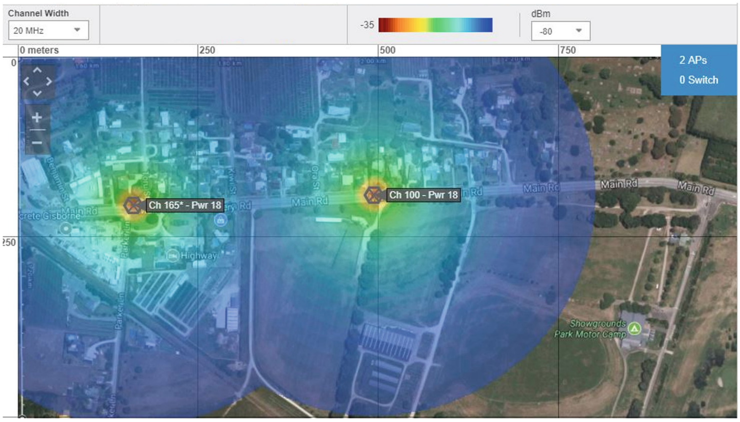

Fig. 7. Basic connectivity (5 GHz) - RSSI heat map 2

4.4 High Speed Connectivity- 5 GHz

Figures 8 and 9 below show the RSSI Heat map when six access points are placed at the positions specified in Table 2.

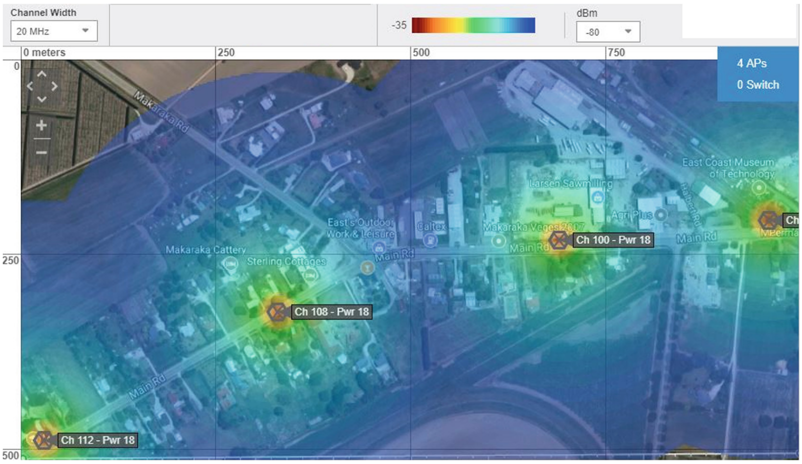

Fig. 8. High-speed connectivity (5 GHz) - RSSI heat map 1

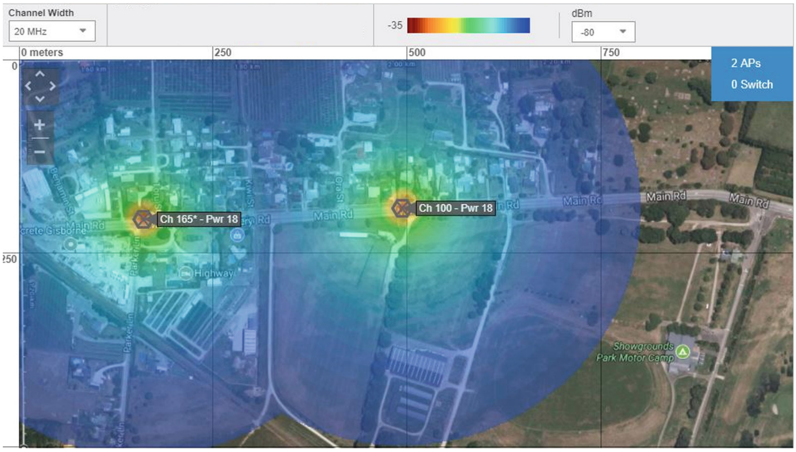

Fig. 9. High-speed connectivity (5 GHz) - RSSI heat map 2

5 Wireless Network Requirements

In order to connect to Wireless Network, users are required to open SSID with a web portal so that a secure connection can be established. The client types for wireless network are 802.11a/b/g/n smart devices from locals and visitors. Client applications and network use is limited to Internet access for web browsing and email. The network is expected to support mobility that is users might move around while using their devices and will get coverage from multiple APs on the go. With the help of the proposed design, we can say that

- The Root Access Point to Mesh Access Point ratio is 10 Mesh Access Points per Root Access Point.
- The maximum recommended distance between two APs is 500 meters.
- An area of around one square km (1 km^2) comprises of three cells minimum and can be covered with two or more hops.

6 Limitations of the Model

- The number of users within the specified coverage area of an AP are not known. It is expected that with the correct number of users, the requirement of the access points might increase which may increase the cost of the network.
- The attenuation and noise present at the specified location of APs is not known. With practical Radio frequency spectrum analyser and calculation of attenuation and noise at the locations of Access points, the coverage and rate parameters may vary.
- The total cost of the model may vary if more number of access points need to be deployed to meet the data demand for more number of users.

7 Conclusion

In this paper, we have proposed an outdoor broadband coverage model for Makaraka area in the region of Gisborne. The proposed model provides basic and high speed connectivity to the central area under two different frequency schemes. We have highlighted the physical installation locations along with the expected throughput that can be achieved. A future extension of this work is the testing in the real environment of Makaraka which can help in further improvement of the design.

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