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Improving Telecommunication Infrastructure in Rural Communities: Signal Strength and Path Loss Evaluation in Selected Communities

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ABSTRACT

The study evaluated the signal strength and proposed improvements in telecommunication infrastructure in rural communities of Binalbagan, Negros Occidental. Three communities were selected, namely Barangays Enclaro, Payao, and Bi-ao, where signal strength was determined, uplink and downlink budgets were calculated, cell radius was calculated, and the the base transceiver station was proposed. Based on the measurements of signal strength across three telecommunication networks, Smart Communications, Inc. (Smart), Globe Telecom, Inc. (Globe), and DITO Telecommunity Corporation (DITO), the following results were as follows. Based on the time of measurement that occurred in 2021, for Brgy. Enclaro, the average signal strengths were -107.85 ± 1.50 dBm (Smart), -92.1 ± 2.67 (Globe), and -101.55 ± 2.82 dBm (DITO). For Brgy. Payao, the average signal strengths were -83 ± 1.08 dBm (Smart), -84 ± 1.59 (Globe), and no signal for DITO. For Brgy. Bi-ao, the average signal strengths were -107.45 ± 3.33 dBm (Smart), -109 ± 2.77 dBm (Globe), and no signal for DITO. The uplink budget was calculated to be 197.68 dB, while the downlink budget was calculated to be 168.50 dB. The cell radius was calculated to be 13.27 km. Various coordinates were presented as possible locations for base transceiver stations. These findings present the need to address communication gaps, especially in terms of augmenting the signal strength to provide access to the rural communities.

INTRODUCTION

Establishing communication consistency is a hallmark indicator of a smart city, which is geared toward ensuring that the connections among constituents are maintained in a manner that would promote global reach (Joshi et al., 2016). In the inherent construct of understanding the communication and its role in various communities, one must establish the baseline parameters that are needed to ensure a continuous chain being maintained. The transmission perspective has continued to evolve vis-à-vis the global economy, especially with the rapid increase of intercontinental communication being the foundation of interaction among various entities (Warf, 2017). With the rapid increase of telecommunication demands, the corresponding effort must be done to facilitate such need through innovative approaches and sustainable measures.

The Philippines has reported the inherent potential growth in the aspects of social and environmental perspectives when considering the integration of the telecommunications industry in such engagement (Miranda-Quibot et al., 2020). In view of this direction, active engagement is being done by the telecommunication companies in the spirit of providing access to communities, both urban and the rural. Through this context, the need to determine areas of need is apparent, especially through the exploration of the possible sites wherein telecommunication access would be needed. As noted in Barela et al. (2019), the rural connectivity gap continues to remain a strain in the delivery of quality service to the people, which potentially presents the issue on sustainability as an evident long-term problem. As examined in a paper by Ortiz et al. (2017), the action toward redefining the infrastructure of the Philippine telecommunication situation would involve structural reforms that would involve prioritization and regulation being improved to enhance the delivery of services. What is important is to cultivate a system that would promote proactive outcomes, which would then be geared toward improving the communicative landscape at hand, which would depend on the balance between the investment and the enhancement of coverage.

The technology behind communication involves looking into the wireless aspects, such as the fourth-generation technology or the 4G technology. While the advanced fifth-generation technology or 5G is still in its infancy in the country, the more stable kind of the 4G technology. According to Kumar et al. (2013), 4G technology is a wireless access communication system that offers significantly faster data transfer than its predecessor, 3G, which would be useful in the aspect of promoting better communication. Additionally, the core technology of the 4G network involves the use of Long Term Evolution (LTE), which has advanced modulation techniques that would optimize bandwidth usage. A community must have access to a 4G network so that the communication needs may be addressed with minimal delay. The importance of determining the need to establish the augmentation of the network is due to understanding the signal strength at hand. Signal strength remains a critical factor in the communication systems environment because of the importance emphasized in data transmission quality, efficiency, and reliability (Maral et al., 2020). Signal strength is important because it indicates the proximity of the transceiver station and the potential for the optimization of the communication system at hand. The determination of signal strength is an important parameter in the context of ensuring that sufficient access to the network is evident in a given area. The signal strength, which is measured in decibels per milliwatt (dBm), has a typical range of between -110 and -30 dBm. According to Putra et al. (2021), for a 4G network, an excellent signal strength is noted as -90 dBm, with a good signal strength ranging between -91 to -105 dBm, and the dead zone being market at values larger than -120 dBm. The metric at hand would be useful in determining the possible steps to take to improve communication networks. Akintoye (2013) wrote that a 4G system must reach target peak data rates of about 100 Mbits/s for high mobility, such as in mobile access platforms. For low-mobility such as local wireless access, the data rates must reach approximately 1 Gbit/s.

In the 4G network, a base transceiver station (BTS) is a permanent location wherein mobile cellular networks are connected, so that the signal may be transmitted as effectively as possible (Ajibola et al., 2015). The BTS is an access point so that the radio communication between a mobile phone and the network may occur, promoting data transmission.

One BTS covers 120 degrees in an area, so the design of a BTS would involve three in one location to ensure a 360-degree coverage being done. To be able to design a base transceiver station effectively, considering the link budget is vital (Pramono et al., 2020). The parameters involved in radio planning are: base station maximum transmission power, the base station antenna gain (specific to the manufacturer), cable loss between the transmitter to the antenna, base station equivalent isotropic radiated power (EIRP), User Equipment (UE) Radio Frequency Noise Figure, the terminal noise, the signal-to-noise ratio, the interference margin, the UE antenna gain, the control channel overhead, and body loss (Sharma et al., 2016). These parameters are essential in calculating the link budget, which, according to Pramono et al. (2020), involves the calculation of the gains and losses of a signal in a communication system.

This study focused on examining the signal strength of selected sites in Negros Occidental, particularly around Binalbagan, a municipality in which the researchers were able to establish the baseline locality. This baseline was established because of prior research done in terms of how the population has expressed the need to improve in terms of the communication aspect. The assessment of communication was designed with the determination of signal strength in Barangay Enclaro, Barangay Payao, and Barangay Bi-ao, three of populated villages in the municipality. The determination of the signal strength, link budget, the cell radius, and the cell location have been done to establish the mechanism in providing possible solutions for communicative expansion. The focus of the study on these areas is designed based on the continuing engagement with the municipality in terms of improving local governance initiatives.

METHODOLOGY

The study employed a quantitative descriptive research design that involved the signal strength measurements at specified locations. The approach of the signal strength measurement is to provide the baseline wherein the introduction of a transceiver station would be evident in the steps that would be taken to improve communication (Anand et al., 2021).

The location of the data gathering took place in three villages in Binalbagan, Negros Occidental (10° 7′ North, 122° 59′ East, estimated 159.6 m above sea level). The municipality is a coastal one in the province of Negros Occidental, with a land area of 74.34 square miles (189.96 square kilometers). The first locality was Barangay Enclaro (10° 11′ North, 122° 51′ East, estimated 5.4 m above sea level). The second locality was Barangay Payao (10° 11′ North, 122° 57′ East, estimated 29.3 meters above sea level). The third locality was Barangay Bi-ao (10° 7′ North, 122° 59′ East, estimated 159.6 meters above sea level). The selection of the sites was based on the ocular inspection of the pertinent areas that were known for participants expressing the need to enhance communication access.

The researchers conducted a signal strength assessment using a 4G mobile phone equipped with the application to be able to determine the Received Signal Strength Indicator (RSSI) in dBm. Twenty trials were conducted over the three different most active networks in the area, namely Smart Communications, Inc., Globe Telecom, Inc., and DITO Telecommunity Corporation. The average RSSI was calculated, and the information was used to calculate the link budget and propagation path loss.

The link budget, which involved the calculation of the uplink and downlink budgets, which are important in the design of communication systems (Ya'acob et al., 2019). The uplink budget is calculated by inputting the following parameters at a data rate of 384 kbps. For the transmitter (LTE User Equipment), the parameters are as follows. For the maximum transmission power in dBm, it is assumed to be 23 dBm, the antenna gain (dBi), it is assumed to be 0 dBi, the body loss (dB), it is assumed to be 0 dB, and the Equivalent Isotropic Radiated Power (EIRP, dBm), which is the sum of the previous parameters. For the receiver, the assumptions would be used are as follows. The noise figure (dB) is 2.2 dB, the thermal noise (dBm), is calculated based on a 290-K temperature at 360 kHz frequency. The receiver noise floor (dBm) is the sum of the noise figure and the thermal noise. The signal-to-inference-plus-noise ratio (dB) is assumed to be -1.28 dB. The receiver sensitivity (dBm) is to be calculated as the sum of the Receiver Noise Floor and the SINR. The interference margin (dB) is assumed to be 4 dB. The cable loss (dB) is assumed to be 0.4. The receiver antenna gain (dBi) is assumed to be 18 dBi. Finally, the Mast Head Amplifier (MHA) Gain (dB) is assumed to be 12 dB.

To calculate the maximum path loss for the uplink budget, equation 1 was used:

Maximum Path Loss (Uplink) = EIRP-Receiver Sensitivity-Interference Margin-Cable Loss+Receiver Antenna Gain+MHA Gain (1)

For the downlink budget, the following parameters were considered at the data rate of 384 kbps (Ya'acob et al., 2019). For the transmitter (eNode B), the maximum transmission power (dBm) was 43 dBm. The antenna gain (dBi) was 18 dBi. The body loss (dB) was 2 dB. The EIRP (dBm) was calculated as the sum of the three parameters. For the receiver (LTE UE), the following parameters were considered. The noise figure (dB) was 4 dB. The thermal noise (dBm) was likewise calculated considering the 290-K temperature at 360 kHz frequency condition. The receiver noise floor (dBm) was calculated as the sum of the noise figure and the thermal noise. The SINR (dB) was presumed to be -10 dB. The receiver sensitivity (dBm) was calculated as the sum of the receiver noise floor and the SINR. The interference margin (dB) was assumed to be 4 dB. The control channel overhead (dB) was 1 dB. Both receiver antenna gain (dB) and body loss (dB) were 0 dB.

To calculate the maximum path loss for the downlink budget, equation 2 was used:

Maximum Path Loss (Downlink) = EIRP-Receiver Sensitivity-Interference Margin-Control Channel Overhead+Receiver Antenna Gain+Body Loss (2)

For the propagation path loss models to be used for average signal propagation values and the calculation of the cell radius range, Sharawi (2010) presented the Okumura-Hata model, which involves various assumptions. The equation 3 was used, considering a medium-sized city.

$$L_u = 69.55 + 26.16 * \log(f) - 13.82 * \log(h_B) - C_H + [44.9 - 6.55 * \log(h_B)] * \log(d) \tag{3}$$

The variables were as follows: L_u is the path loss in urban areas (dB), h_b is the base transceiver station antenna height (m), h_M is the mobile station (UE) height (m), f is the transmission frequency (MHz), C_H is the antenna height correction factor (dB), d is the distance between BTS and MS (km). C_H may be computed using equation 4:

$$C_H = 0.8 + (1.1 * \log 2500 - 0.7) * 1.5 - 1.56 * \log(2500) \tag{4}$$

It is noted that the possible outcomes are based on the theoretical maximum outcomes, which are still subject to equipment considerations and other external factors.

RESULTS, DISCUSSION, AND IMPLICATIONS

The following results show the signal strength at the sites (Brgy. Enclaro, Brgy. Payao, and Brgy. Bi-ao), the calculated link budgets, the computer cell radius, and the recommended sites of the base transceiver stations (BTSs). These results capture the essence of providing initial outcomes for the policymaking body to promote solutions toward enhancing

Figure 1
Signal Strength at Brgy. Enclaro

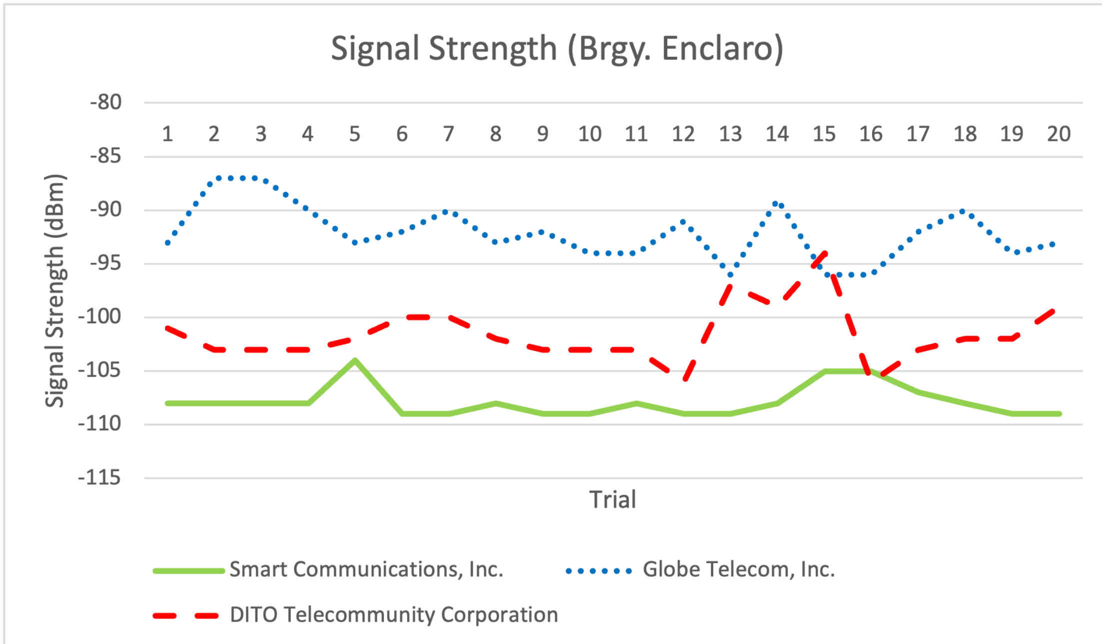


Figure 2
Signal Strength at Brgy. Payao

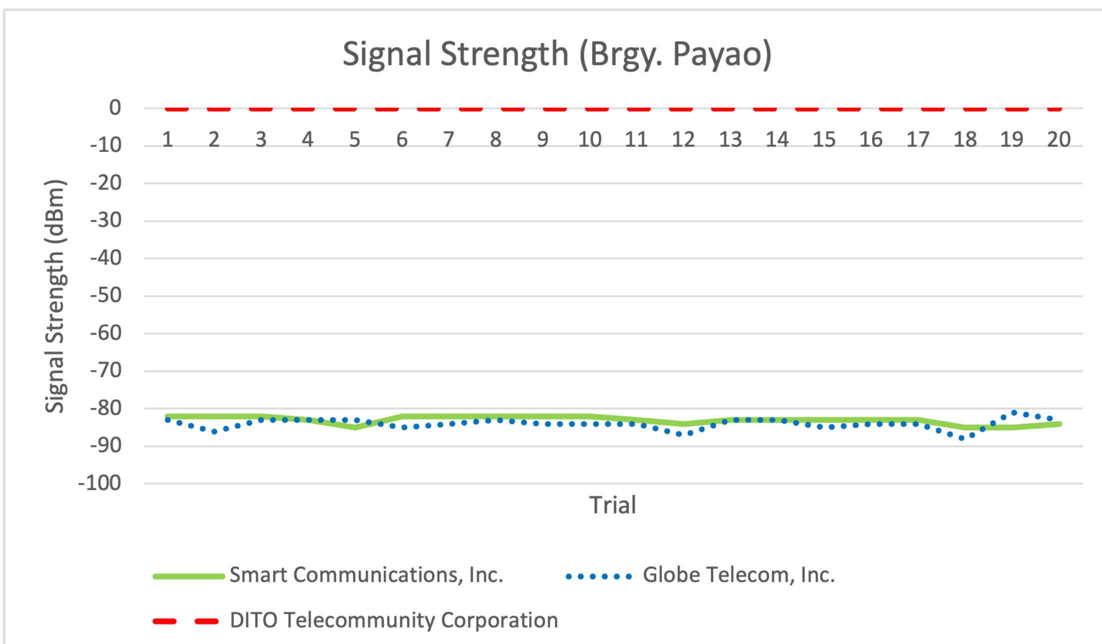
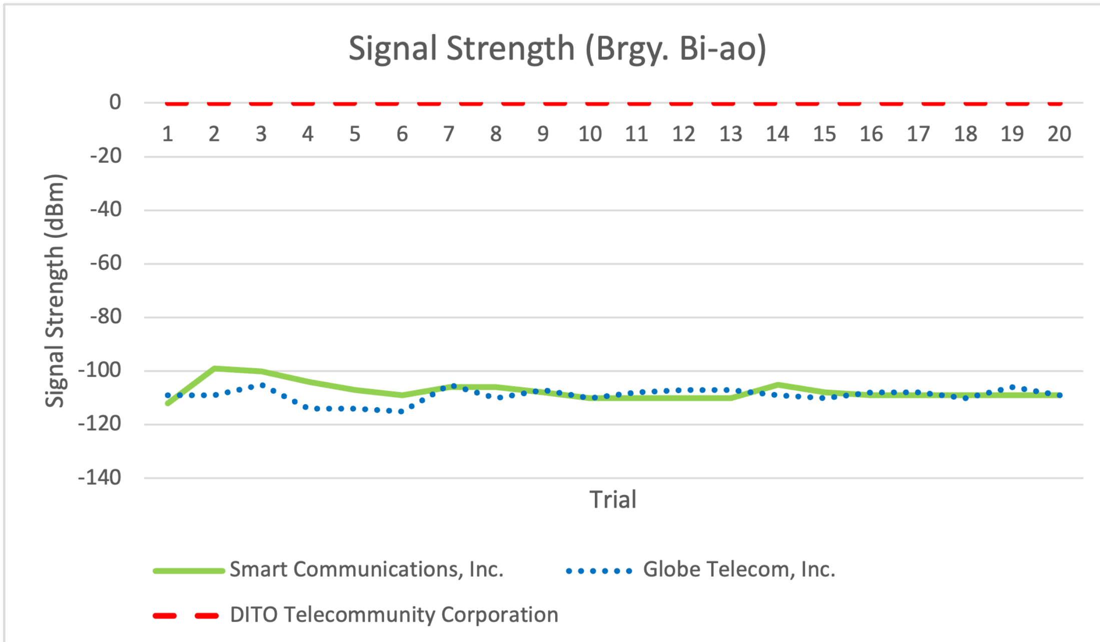


Figure 3
Signal Strength at Brgy. BI-ao



communication access to the people of Binalbagan.

For Brgy. Enclaro, for the Smart Communications, Inc., network, the mean signal strength was -107.85 dBm (SD = 1.50 dBM), which corresponds to a fair signal strength. Globe Telecom, Inc. had a mean signal strength of -92.1 dBm (SD = 2.67 dBm), which is corresponding to having a good signal strength. For the DITO Telecommunity Corporation, the mean signal strength was -101.55 dBm (SD = 2.82 dBm), which is a good signal strength. All three networks have sufficient coverage in Brgy. Enclaro.

For Brgy. Payao, for the Smart Communications, Inc., network, the mean signal strength was -83 dBm (SD = 1.08 dBm), which is an indication of excellent signal strength. Globe Telecom, Inc. had a mean signal strength of -84 dBm (SD = 1.59 dBm), which is also an excellent signal strength indication. For the DITO Telecommunity Corporation, no signal was measured. Only two of the three networks have sufficient coverage in Brgy. Payao, with DITO having no coverage as of the assessment time.

For Brgy. Bi-ao, for the Smart Communications, Inc., network, the mean signal strength was -107.45 dBm (SD = 3.33 dBm), which indicates a fair signal strength. Globe Telecom, Inc. had a mean signal strength of -109 dBm (SD = 2.77 dBm), which is also an indication of fair signal. For the DITO Telecommunity Corporation, no signal was measured. Only two of the three networks have sufficient coverage in Brgy. Bi-ao, with DITO having no coverage as of the assessment time.

The signal strengths assessment provides sufficient insight on what networks need augmentation in the various areas (Warf, 2017). For all barangays, Smart Communications, Inc., and Globe Telecom, Inc., performed well in terms of signal coverage. DITO Telecommunity Corporation was present only in Brgy. Enclaro, and the need for augmentation is evident for the remaining barangays.

For the uplink budget, the following calculations were applied to the specified terms. The EIRP was calculated to be 23 dBm. The thermal noise was calculated to be -174 dBm. The receiver noise floor was calculated to be -171.8 dBm. The receiver sensitivity was calculated to be -173.08 dBm. Using equation 1, the maximum path loss for the uplink was calculated to be 197.68 dB.

For the downlink budget, the following calculations were applied to the specified terms. The EIRP was calculated to be 63 dBm. The thermal noise was calculated to be -104.5 dBm. The receiver noise floor was calculated to be -100.5 dBm. The receiver sensitivity was calculated to be -110 dBm. Using equation 2, the maximum path loss for the downlink was calculated to be 168.5 dB.

These figures represent the allowable attenuation of signal strength so that the performance metrics are achieved as desired (Warf, 2017). Maintaining these values would entail proper design aspects and sufficient modification to respond to external elements.

Using equation 3, the cell radius range was calculated as follows. Primarily, equation 4 was used to calculate the antenna height correction factor, considering a frequency of 2500 MHz, which produced a result of 0.056. Furthermore, considering the maximum path loss of the downlink budget as the design parameter in which the value may not exceed, with the antenna height of 80 meters, the mobile station height of 1.5 meters, and the frequency of 2500 MHz, the cell radius was calculated to be 13.27 km. According to Sharawi (2010), the consideration of designing sufficient cell towers must be aligned with the need to maintain adequate communication measures. Adjusting the parameters such as the transmission frequency and the antenna height may also produce variable outcomes as desired.

Based on the information presented, the following sites have been proposed. The proposed site for Barangay Enclaro BTS has a latitude of 10010’34.03” N and a longitude of 122051’29.40”. The proposed site for Barangay Payao has a latitude of 10010’22.87” N and a longitude of 122056’52.52”. The proposed site for Barangay Bi-Ao has a latitude of 100’7’11.43” N and a longitude of 122058’55.73”. The determination of the site is based on the baseline parameters of ensuring that sufficient coverage is designated for the given village.

CONCLUSION AND RECOMMENDATIONS

Communication remains a vital premise in the promotion of interaction and in the development of communities. The critical role of the communication through the lens of telecommunication has been noted in various rural areas in the province of Negros Occidental. Major networks have adequate coverage in the area, such as that evident for Smart Communications and Globe Telecom, Inc. However, augmentation is needed for DITO Telecommunity Corporation, so that coverage gaps may be assessed. The uplink and downlink budgets as well as the cell radius provide sufficient insight in the construction of possible base transceiver stations in the areas, so that the telecommunication engagement may be supported and engaged.

It is recommended that a time-based analysis be done to determine spatial perspectives over a given time, so that further modeling may be implemented. Moreover, it is recommended to expand the signal strength analysis to other parts of the municipality, so that communication assessments may also be done.

The proactive approach taken in the promotion of sustainable communication infrastructure is vital in the condition of promoting socioeconomic growth. The communication aspect of any given society would involve a more engaged approach that would serve to strengthen rural areas in the field of data transmission and communicative outcomes. Global connections remain vital in the premise of telecommunications, and the need to augment such in various communities remains the call of the nation toward sustainable development.

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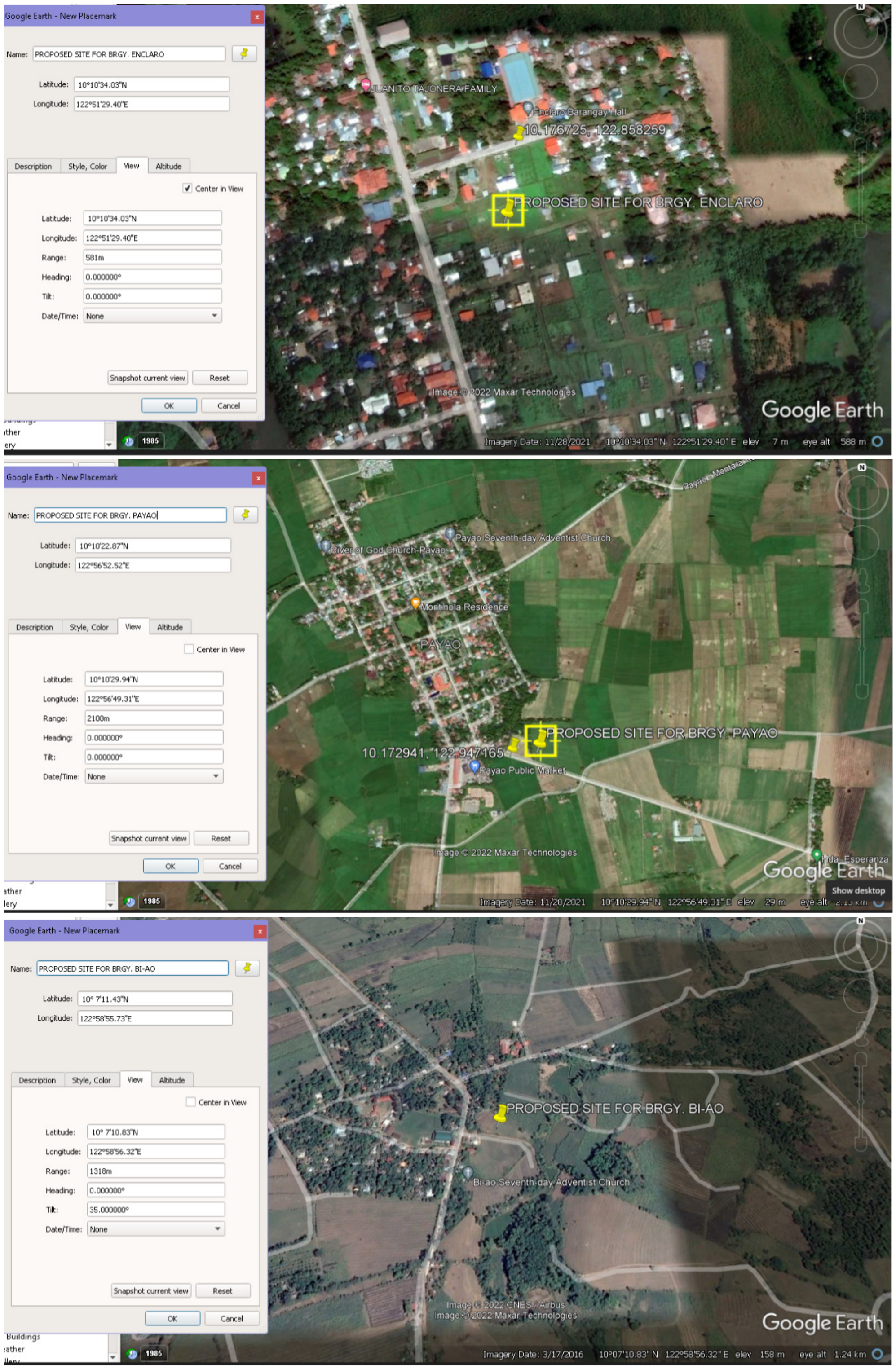
Figure 4
Proposed BTS locations for Brgy. Enclaro, Brgy. Payao, and Brgy. Bi-ao



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