Comparison of goTenna and ClusterDuck Protocol: Evaluation of the Performance under Various Conditions

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***Abstract*—Natural catastrophes cause widespread damage, including the destruction of communication infrastructure; When communication infrastructure goes down, people can no longer send SOS signals or messages for help. Furthermore, with previous problems, the frequency of natural disasters and the necessity for communication systems in emergencies is rising every year. For these reasons, companies and organizations have developed innumerable technologies focused on disaster relief. However, there is a lack of comparative research on the practical application of communication technology in this emergency environment. Therefore, two technologies (goTenna and ClusterDuck Protocol) had changes in their Received Signal Strength Indicator (RSSI) and Message Delivery Ratio (MDR) compared over a variety of environments and differing ranges. This study aims to compare the transmission range of two technologies under various conditions and provide guidance for selecting the appropriate technology based on specific use cases. By analyzing the results, this study seeks to identify the strengths and weaknesses of each technology and provide insights into their optimal use cases.**

***Index Terms*—goTenna, ClusterDuck Protocol(CDP), LoRa, Aspen Grove, Mesh Network**

I. Introduction

According to the United States Geological Survey (USGS), the amount of vapor evaporated as the temperature rises due to climate change is increasing [1]. The presence of water vapor strengthens storms by providing additional energy. The Wisconsin Department of Natural Resources (WIDNR) mentioned in their research that the Earth's temperature increased by an average of 1 degree Celsius from 1880 to 2019 and is expected to rise even faster [2]. In the end, natural disasters such as hurricanes and snowstorms are predicted to increase in the near future. Further supporting these claims, the National Oceanic and Atmospheric Administration (NOAA) published data stating that the frequency and damage of natural disasters are increasing [3]. These acts of God have the potential to damage or destroy infrastructures for cellular service.

These devices are used not only for natural disasters; there are situations in which cellular services are not available such as cellular congestion (e.g., large events, festivals, sports), sensor networks (e.g., Farmland or offshore industries), and more. There are several technologies for these situations, such as goTenna, ClusterDuck protocol (CDP), and Beartooth. Among them, goTenna and CDP are the primary focus of this project. This document compares how the performance of goTenna and CDP is affected in various conditions.

GoTenna and CDP, developed as a means of communication in case of natural catastrophes [4][5], are also used in any cases where wireless communication is difficult (e.g., mountainous areas, cell congestion, war). Even if there is barely any infrastructure, Long Range Radio (LoRa) enables each user to become a node to form a mesh network and establish a wide range of communication networks in the end [6]. Each node sends the transmitted data to the surrounding nodes, allowing them to receive data from end devices at a long distance.

Although made for the same purpose and used in similar situations, these products have technical differences. GoTenna constructs a mesh network using Aspen Grove: a proprietary technology developed directly by the company, making it possible for more data to be transferred quickly. In addition, since it provides a high-security encryption system, it is utilized in tactical situations such as war. Unfortunately, goTenna is a paid service provided by the company [7].

ClusterDuck Protocol provides similar functionality to goTenna but is open source and available to everyone. CDP is also readily available to the public with affordable hardware and Arduino Integrated Development Environment (IDE) . However, only text messages are available, and the security level is low since it uses the default mesh network [4]. Nevertheless, CDP may be a reasonable choice over goTenna in certain situations since quick data transfer and high-security systems are not particularly important in disaster situations.

goTenna and CDP have several differences in their technology and cost. However, there exists a paucity of published comparison papers on the differences between these two technologies. This study aims to conduct a comparative analysis of the performance of goTenna and CDP in three distinct environments to identify the disparities between the two technologies and determine the specific environments and conditions that yield optimal performance for each technology, assisting in the growth of the two services and the experiments that people conduct in the future.

II. RELATED WORKS

Means of communication in situations where disaster or cell communication is not available are becoming increasingly important, and plenty of studies concerning emergency communication are underway. However, the majority of experiments were conducted under diverse conditions utilizing a solitary communication device. Referring to the following related papers, we would like to suggest how to compare goTenna and CDP.

B. S. Goldberg et al. [8] conducted a study comparing goTenna and two-way radio as means of communication in disaster situations where cellular communication is unavailable. However, specific parameters were not measured and compared in this document.

In this paper [9], an Android app that communicates without a mobile network was developed using XBee. This app presented how PDR changes according to distance under conditions such as single-hop and multi-hop as a research result. PDR decreased as the distance increased and the hop count increased.

In [10], the authors present how the indoor performance of LoRa varies with frequency. Received Signal Strength Indicator (RSSI), Signal Noise Ratio (SNR), and Packet Delivery Ratio (PDR) on each floor of a 10-story building was measured to compare performance according to frequency. The results showed higher SNR and RSSI values at 433 MHz and higher PDR values at 868 MHz.

The objective of this research is not solely to assess a single communication technology across diverse conditions but rather to evaluate the performance of CDP and goTenna in varying conditions.

Although many LoRa communication experiments have been conducted, no paper compares the performance of the two technologies with specific parameter values under the same conditions, so we plan to find out how the performance of goTenna and CDP changes under identical conditions by comparing MDR and RSSI values.

In summary, the ultimate goal of the research is to evaluate and compare the performance of goTenna and CDP by verifying whether goTenna can be replaced by CDP in specific environments such as woodland or urban areas.

III. METHODOLOGY

The goal of the experiment is to measure the RSSI and MDR values of goTenna Pro X and CDP in an outdoor environment. The final step of the research is to analyze the results of the experiment to identify the optimal environments and ranges for the effective deployment of goTenna and CDP.

A. Hardware Setup

TABLE I: Hardware Specification

	goTenna	**CDP**
Hardware	goTenna Pro X	LILYGO T-BEAM
Frequency	469 MHz	915 MHz
Antenna gain	5.1 dBi	5 dBi
Transmit power	0.5 Watt - 5.0 Watt	0.1 Watt
Receive sensitivity	-107 dBm	-139 dBm
Battery Life (Standby)	30 + hours	Requires a power source
Battery Life (Nominal)	up to 9 hours	Requires a power source

(a) goTenna Pro X

(b) LILYGO T-BEAM-V1.1

Fig. 1: Hardware Images

The experiments utilized two goTenna Pro Xs and two LILYGO T-BEAMs, each embedded with the MamaDuck code. Details of the hardware are presented in Table 1. Since 915 MHz is a non-licensed free frequency for LoRa [11], CDP uses 915 MHz. Given that the goTenna antenna used in the experiment is a UHF-only antenna, the UHF-only frequency provided by goTenna (445 MHz-480 MHz) should be used [12]. The reason why 469 MHz is used is presented in Figure 2; the frequency less affected by ambient noise was 469 MHz when we were testing. CDP's Spread Factor (SF) has a default value of 7, and goTenna automatically changes the SF value according to the situation. In scenarios such as disaster situations where conventional cellular network services are unavailable, the priority lies in achieving an extended communication range rather than focusing solely on transmission time and data rate. Therefore, the SF value of CDP was increased to 12 for testing purposes. Although increasing the SF improved the communication range, it also resulted in numerous packet losses and corruptions. Consequently, the SF value was reset to the default value of 7 for further testing. Given the discrepancies in frequency and transmission power, a direct comparison between goTenna and CDP would be inappropriate. The comparative results are expected to show that goTenna outperforms CDP. However, within specific ranges or environments, CDP has the potential to surpass goTenna.

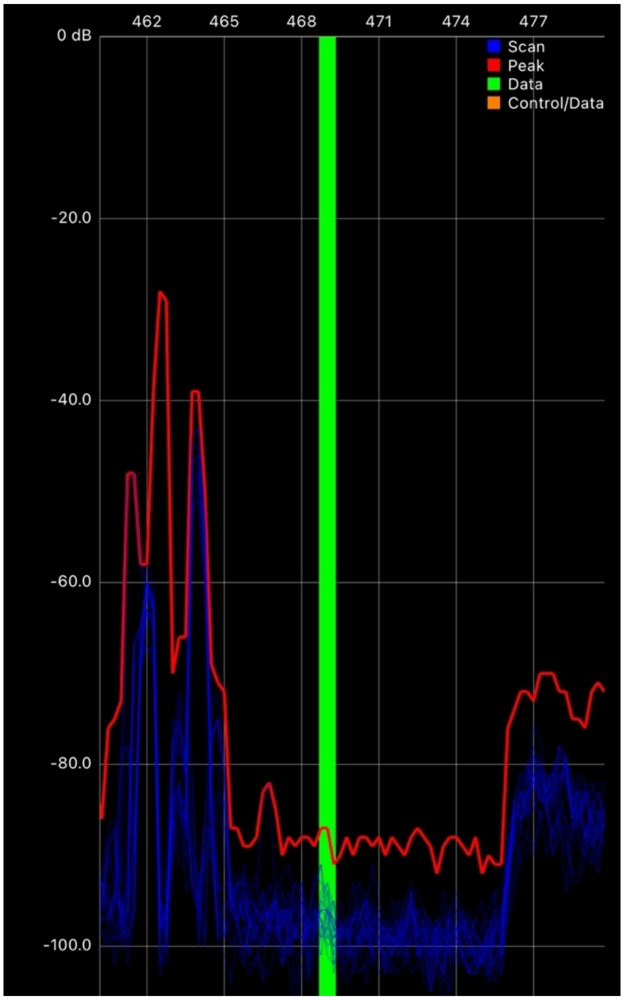


Fig. 2: RSSI Scan: UHF

B. Experimental Model Setup

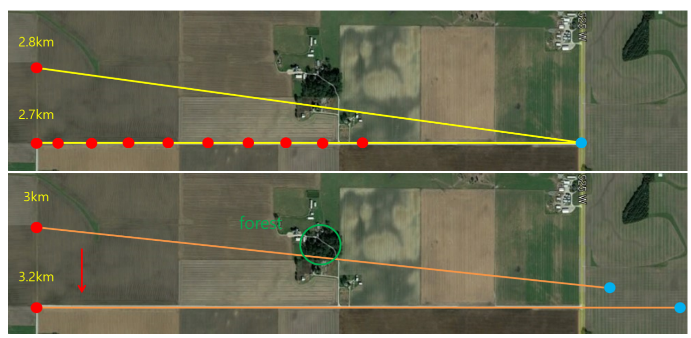
Before testing, the theoretical performance evaluation of goTenna and CDP was conducted using the Okumura-Hata Model [13]. Based on the criteria outlined in [14], CDP is suitable for use within a range of -120 dBm. Although goTenna's performance is impressive, CDP also offers coverage of up to 4.5 kilometers in open areas and 1 kilometer in urban environments.

The topography and distance of the test environments are presented in Figure 3-5. The RSSI and MDR values were measured between the blue and red points presented in Figure 3 (a), Figure 4 (a), and Figure 5 (a). The measurements were taken at different locations in three environments: a farm, a golf course, and woodland. On the farm, the measurements were taken at intervals of 100-200 m from 1-3.2 km apart. On the golf course, measurements were taken at 400 m, 800 m, 1 km, 1.1 km, 1.2 km, 1.3 km, 1.4 km, and 1.5 km. In the woodland, measurements were taken at 200 m, 400 m, 500 m, 600 m, 650 m, and 700 m. The average RSSI and MDR values were calculated from 10 transmitted messages. The message transmission interval of goTenna and CDP was about 2 seconds. The data size of the message was fixed at 5 bytes. The antenna of goTenna and CDP was held by hand 1.5 meters above the ground in all measurements. Although antennas were placed at the same height of 1.5 meters on the ground, the effects of the Fresnel zone on the received signal of goTenna Pro X and CDP are different due to frequency differences. The radius of the Fresnel zone can be calculated using the following equation [15].

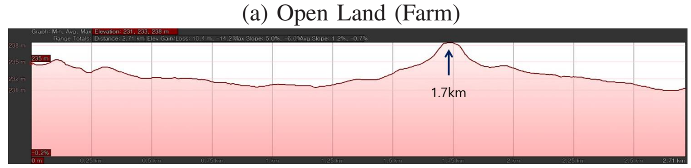
$$R(m) = 17.31 \times \sqrt{\frac{d(km)}{4000 \times f(MHz)}} \tag{1}$$

where, R is the Radius of the fresnel zone in km, d is the distance between antennas in km, and f is the radio frequency in MHz.

The radius increases as lower frequencies are used at the same distance. In other words, the antenna should be placed at a higher position to reduce the impact of the Fresnel zone at lower frequencies. Therefore, even if the antennas are located at the same height of 1.5 meters on the ground, the goTenna Pro X is more affected by the Fresnel zone than CDP because the radius of the goTenna Pro X is more significant than that of the CDP. The distance was estimated using the GPS function of Google Maps and the distance measurement function of goTenna Pro X.



(a) Open Land (Farm)



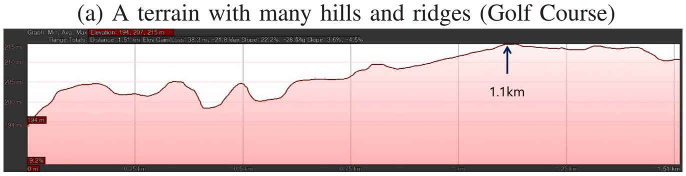
(b) Elevation

Fig. 3: Topography & Environment of Farm

IV. Results and Discussion

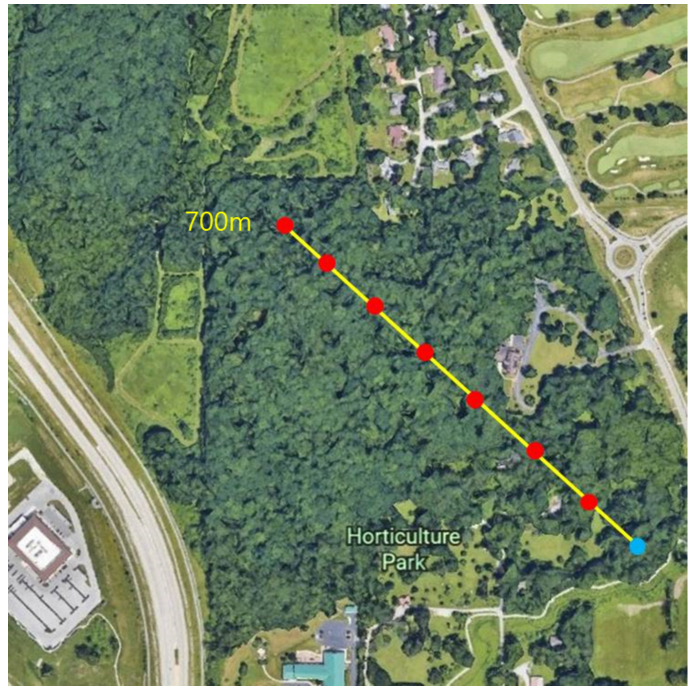
During the farm test, the environmental conditions were as follows: the temperature was 10 °C, the humidity was 51%, and the wind speed was 6 m/s. On the other hand, when the

(a) A terrain with many hills and ridges (Golf Course)



(b) Elevation

Fig. 4: Topography & Environment of Golf Course



(a) A terrain with many obstacles (Woodland)

(b) Elevation

Fig. 5: Topography & Environment of Woodland

tests were conducted on the golf course and in the forest, it was after the rain had stopped, so the humidity was high at 90%, the temperature was 0 °C, and the wind speed was 7 m/s.

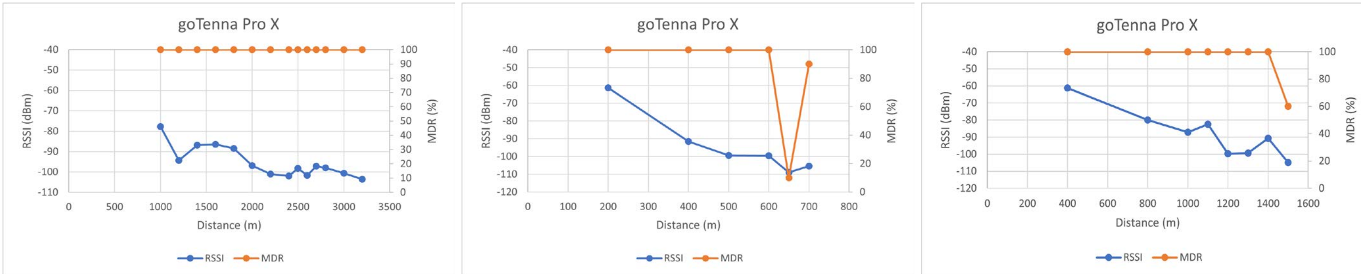
A. *Open Land (Farm)*

The initial test plan was to measure the RSSI and MDR at an interval of 200 m from 1 km to 2 km. However, since both goTenna and CDP showed good performance, we extended the range to 3.2 km. At the 3 km point, as depicted in Figures 3 (a) and 7 (a), low MDR and RSSI values were observed, which were not part of the scheduled measurements and were attributed to interference from the forest. At a distance of 3.2 km (from a forest-free location), the measurement results demonstrated that the CDP displayed an MDR value of 80% and an RSSI value exceeding -130 dBm. Although there were no apparent obstacles or hills beyond the 1.7 km point, as depicted in Figure 3 (b), the reason for the improved performance observed at 2.8 km remained uncertain. To investigate this further, the measurements were repeated on the return path; however, the results were similar to the previous measurements. The goTenna Pro X demonstrated a 100% MDR at an RSSI value exceeding -105 dBm, whereas the CDP exhibited an MDR value of 95% at an RSSI value surpassing -120 dBm. The CDP exhibits a somewhat analogous ascent and descent tendency concerning RSSI and MDR values, and a surge in the frequency of dropped messages is detected as the RSSI diminishes below -130 dBm. This was a foreseeable outcome grounded on the Receive sensitivity demonstrated in Table 1.

B. *A terrain with many hills and ridges (Golf Course)*

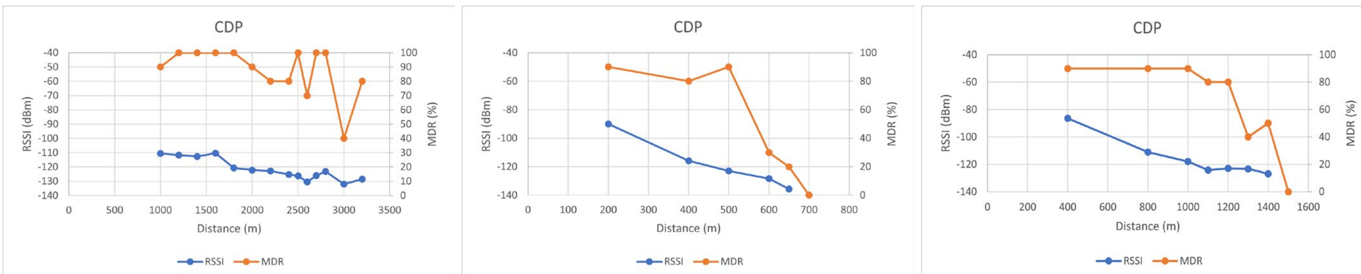
The measured RSSI and MDR values are presented in Figure 6-7. In the case of CDP, message drops were observed at a low rate even in close proximity, even more so as the RSSI declined below -120 dBm. On the other hand, for goTenna, message drops were observed as soon as the RSSI value dropped below -100 dBm. At the 1.1 km point, the RSSI value of goTenna Pro X increased compared to that at the 1 km point, whereas CDP's RSSI value remained unchanged. The Fresnel zone radius of goTenna is larger than that of CDP due to the frequency difference, as explained in Equation 1. The Fresnel zone radius of goTenna and CDP are determined to be 13.3 m and 9.5 m, respectively, at a distance of 1.1 km.

As a result, to achieve optimal performance beyond the limitations imposed by the Fresnel zone, goTenna requires a higher elevation. This is demonstrated in Figure 4 (b), which



(a) Farm (b) Woodland (c) Golf Course

Fig. 6: goTenna Pro X



(a) Farm (b) Woodland (c) Golf Course

Fig. 7: CDP

shows that the elevation at 1.1 km is 3 m higher than that at 1 km.

This additional elevation plausibly contributed to the improved performance of goTenna. Notably, changing the measurement location could yield completely different results even within the same golf course due to the irregular placement of hills and obstacles. Therefore, the results obtained in this study are limited to the specific measurement locations and should not be generalized to other areas.

C. A terrain with many obstacles (Woodland)

In woodland, similar to other environments, it is observed that goTenna can transmit messages reliably above -100 dBm. However, message drops began to occur when the RSSI of the signal dipped below -100 dBm. CDP also shows a significant decrease in MDR from a distance of 600 m. In woodland, the results of the experiment indicate that despite the increase in distance from 500 m to 600 m, the RSSI value of goTenna only exhibited a slight increase. As observed during the experiment conducted on the golf course, goTenna's optimal performance can be achieved by operating at sufficient elevation to avoid the effect of the Fresnel zone. Figure 5 (b) depicts that the highest altitude is achieved at a distance of 600 m and that there is a valley in the vicinity of 650 m. In addition to elevation, the irregular tree density in the woodland environment may also have caused the test results to differ from theoretical interpretations.

V. Conclusion

The performance of two wireless communication technologies—goTenna and CDP—was evaluated and compared in three different environments: Farmland, woodland, and a golf course (to simulate hilly terrain). CDP demonstrated performance comparable to goTenna in Farmland up to 3.2 km and in a golf course up to 1.2 km, indicating its potential as a viable alternative to goTenna in communication systems for disaster situations where cellular service is unavailable. CDP is considered to possess the potential to serve as a feasible alternative communication method in rural areas and terrains characterized by hills and ridges within a specific range. Nonetheless, in the forest environment, CDP surpasses goTenna up to 500 m, though its practical usability in small mountains or forests is low due to the minor risk of distress in such areas. Lower frequencies are less affected by humidity or obstacles, as reported in [16]. According to Equation 1, the Fresnel zone radius increases with lower frequencies. Therefore, generally speaking, utilizing goTenna at high elevation is recommended, while CDP is more recommended for use in environments with low obstacles and humidity.

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