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**SMART COMMUNICATION PLATFORM SYSTEM
FOR LOW ALTITUDE APPLICATIONS**

By

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Over the past few years, concerns about disasters in the Pacific Basin have increased significantly. In general, disasters result in massive loss of life and the destruction of property. Once a disaster has occurred, such as an earthquake or a flood, the communication infrastructure is destroyed, including telecommunications towers, optical fiber cables, and base stations for cellular phones (Okada, 2002; Fujiwara et al., 2004). The destruction of the communications infrastructure as a result of a disaster will hinder communication between the affected area and the recovery center.

The Wide Area Disaster Information and Sharing System (WIDISS), which is a kind of web-based, geographical information system, has been used to serve the population and members of local government to enable them to receive accurate and reliable information from the disaster area. However, people outside the affected areas can obtain disaster-related information through the Internet (Echigo et al., 2007). Remote sensing and information exchange from the area where the disaster occurred are priorities that must be addressed in a risk assessment. Wireless communications, in particular, have a role in the effective deployment of networks in disaster areas (Morgan et al., 2006). The traditional network method requires that the communication network infrastructure be viable and functional. This indicates that any defects or damages that occur in any portion of the network's structure can result in interruptions in the

connection to the affected region. The Asia-Pacific disaster report devoted an entire section to a new technology and how it can be used to enhance the management of the risks associated with disasters (Ure, 2012).

A low-level platform to strengthen the communication system was used by the researchers in (Booth & Tueller, 2010), and it can also be used in a state of emergency resulting from sudden-onset disasters. Inoue et al. (2000) proved that low-level balloon systems can be effective in measuring in plant variables. The value of satellite and high-altitude sensors for landscape-level evaluations has been established, but these tools are inadequate for inventory and measurement of the details that are needed for valid conclusions about conditions in the affected areas. New advances in low-altitude remote sensing provide the ability to accurately measure the extent of the disaster's effects and perhaps other indicators (Booth & Tueller, 2003).

A balloon-based, wireless, ad-hoc network method was proposed to ensure prompt communications to acquire information from disaster areas (Shibata et al., 2009). A surveillance system based on a tethered balloon system was chosen because it has simpler permitting requirements and operational requirements than unmanned aerial vehicles (Pegau & Green, 2011).

A low-altitude, aerial platform can be an alternative solution for use in establishing emergency medical communication systems. The experimental results showed that such a system can be established with limited resources and that it can provide an excellent option for establishing an emergency communications system that can be used during a natural disaster (Qiantori, 2011).

In case of an emergency, an Internet gateway with communication capability can be installed on the ground in the disaster area with Sky Mesh to provide Internet access. Balloons are connected wirelessly to the gateway for Internet access. The balloons,

which are beyond the transmission range from the gateway, are connected by multi-hop communication through the ad-hoc network. People in the disaster area be close to the coverage area and still communicate with others who are outside the disaster zone. According to Suzuki et al. (2006), these approaches are currently used as alternatives to terrestrial networks, which can be damaged and rendered inoperable during and after a disaster.

However, the proposed approach was accompanied by real challenges during implementation. The emergency system in a disaster area requires various requisites, such as the balloon's stability and the fluctuations of the signal, be addressed because they can lead to increased data losses between the network nodes, making the monitoring of the disaster area quite limited. The wind speed and flow patterns determined by using helium balloons as stations for wireless access points in mesh networks that requires stable atmospheric conditions.

According to Umeki et al. (2009), researchers have examined the statistical characteristics of wireless channels in a sky mesh to stabilize the quality of communication. The authors observed that the quality of the channel varied due to the swinging of the balloon nodes caused by wind near the surface.

Emergency Broadband Access Network (EBEN) Phase-1 is used at low-altitude to provide wireless broadband service during a disaster. Atmospheric turbulence is one factor that affects the performance of communications systems and their transmission efficiency. In order to maintain the stability of a balloon-based platform in the wind, ropes has been used to achieve stability and secured on the ground. This procedure can mitigate the instability and other disorders to some extent. However, according to Hariyanto et al. (2009), this approach generates new restrictions in that the length and weight of the ropes that anchor the balloons affect the ability of the balloons to rise.

According to Mansur (2012), the second version of EBAN enhanced the previous version to improve the sky station backhaul by including new communication capability. The Wi-Fi solution was selected because of its popularity, and it was relatively easy to deploy. The project seeks to verify the reliability of the Wi-Fi repeater antennas that were installed on the platform. When the platform was at an altitude of 400 meters in the air, the wind factor will cause a change in the coordinates of the platform for its initial state. Changes in wind direction lead to swinging the platform up or down from its original position. The effect of changing the tilt of the Wi-Fi repeater can cause changes in the level of the signal that is received by the client, and the signal may even be lost. In order to provide a robust communication system, the project team designed a Wi-Fi mesh network as a solution for a small-scale disaster area. The left side of Figure 1.1 shows the components of the platform, and the right side of the figure shows the platform being suspended by the balloon.



Figure 1.1: Emergency Broadband Access Network for Disaster Relief in Indonesia Phase-2 (Mansur, 2012)

The situation demands that the rate of data propagation be improved. Thus, the communications network should be distinctive in terms of being reliable, accessible,

and easy to install. Wireless communications, in particular, have a role in the effective deployment of networks in disaster areas. However, it is vitally important that the capacity of the networks be strengthened to ensure that they can adequately accommodate the requirements.

Fiber-optic networks provide the highest bandwidth capacity, but the cost of utilization may limit their deployment. There is a new and ambitious approach in which fiber optics are combined with wireless networking to provide integrated, fiber-wireless (Fi-Wi) networks. The ultimate objective of a Fi-Wi network is the convergence of optical and wireless technologies under a single infrastructure in order to take advantage of their complementary features. Therefore, they can provide a network that is capable of supporting the required bandwidth applications to meet the growing demand for a seamless technique for both fixed and mobile base stations.

Low-altitude platform stations have been used to optimize communications in various applications. In cases that utilize radio-and-fiber network architectures to improve the communication performance, the situation demands the use free-space optics (FSO) with wireless networks to connect the nodes of the network. Optical wireless, based on FSO-technology, requires LoS between both transmission sides. Achieving a LoS requires stabilizing the FSO platform. Previous studies and concepts pointed to the significance of using aerial platforms as well as the challenges of deploying the network.

The existing situation requires determining appropriate solutions to address these challenges. For those reasons, this study sought to find suitable solutions that make utilizing L-AP technology accessible and efficient.

1.2 Problem Statement

Natural disasters cause massive destruction, which leads to the loss of life and the destruction of property. In the wake of disasters, communication is essential to rescue people and provide prompt assistance to those who are affected. Thus, Pacific nations began to focus on the role of communication in reducing the impact of disasters. The main problems in isolated areas are communication and accessibility to minimize the effects of the disasters, and aerial platform systems will enable the re-linking of isolated areas with the global network. Figure 1.2 shows the topology approach that was used throughout this study.

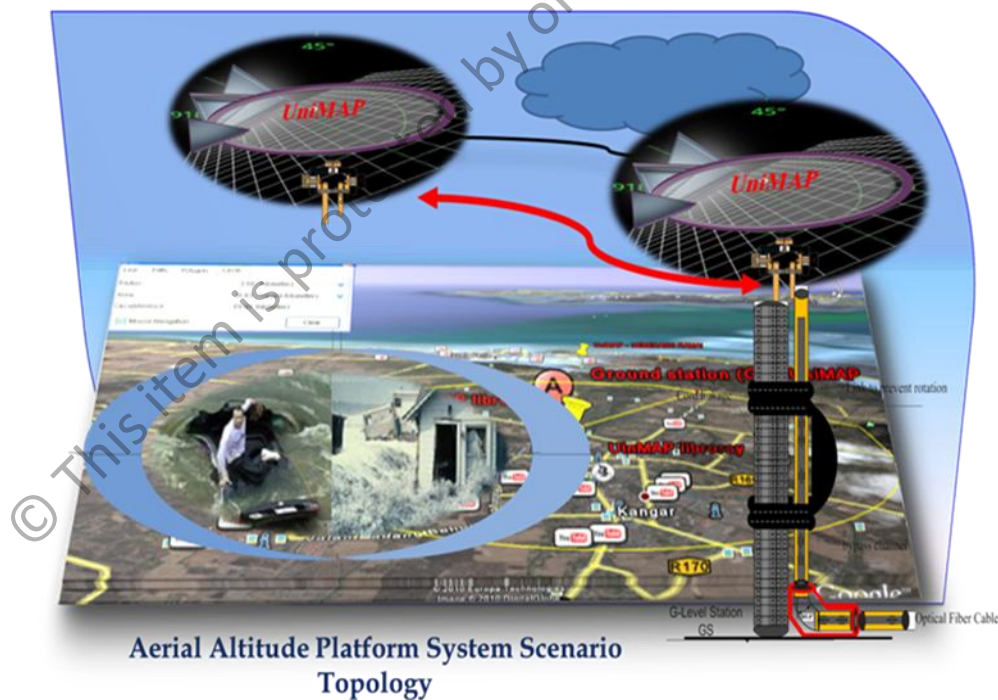


Figure 1.2: Topology of Low-Altitude Platform Systems

Aerial platform technologies can be used as an alternative due to the damage that occurs to the terrestrial network infrastructure during a disaster. The low-altitude platform system is a technique that has been used to enhance the communications

network. However, this idea is still faced with certain challenges that must be resolved as a result of environmental factors, i.e., the instability of the communication system inside the aerial platform and the need to improve the capacity of the network to satisfy requirements. In fact, there is a correlation between these restrictions. The swinging of the communication platform as a result of environmental factors can result in loss of the line-of-sight between the nodes of the network.

Free-space optics communication links offer the potential for enhanced communication at high data rates between the deployed nodes. However, these have narrow beam divergence and require guidance by laser beams in the free space between the bi-directional FSO systems. Moreover, the attenuation in the transmission channels as a result of turbulent weather can cause an unacceptable bit error rate (BER) at the FSO receiving side. Previous limitations have hindered the deployment of such communication networks. Figure 1.3 illustrates the limitations that have adversely affected the performance of low-altitude platforms.

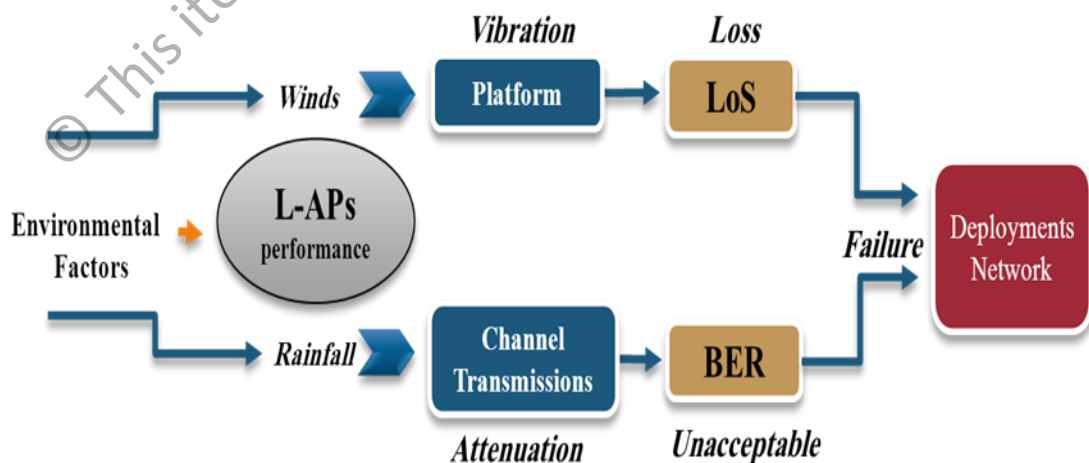


Figure 1.3: Impact of Weather on the Performance of L-APs

These conceptualizations demand the establishment of a smart communication platform system (SCPS) as a telecom air station. The system must be characterized by the ability to adjust the external factors that prevent the stabilization of the platform in order to maintain line-of-sight signal propagation. Furthermore, the stability of the SCPS will enhance the capability of the bi-directional FSO system on a mobile platform as a method for improving the propagation of data. Moreover, a new approach was used to connect several aerial platforms at multiple levels to deploy network nodes with terrestrial remote sensing.

1.3 Research Objectives

The aim of this study was to develop a low-altitude, aerial platform in order to overcome the imposed restrictions during application, specifically in emergency applications. This study sought to achieve the following objectives.

- I. To create smart communication platforms that is compatible with the level of deployment.
- II. To optimize the rate of data transmission between the nodes of the network with acceptable BER.
- III. To design a controller system that has the ability to achieve stability and that provides an uninterrupted line-of-sight between the bi-directional FSOs.
- IV. To evaluate the performance of the system in different environmental conditions in order to verify its portability and operational effectiveness under these conditions.

These objectives are focused on addressing the current deficiencies in the performances of deployed networks.

1.4 Scope of Research

This thesis provides a new approach that can be used for aerial platforms at low altitudes. It is an effective alternative for several applications, e.g., it can be utilized in cases in which natural disasters have caused damage to or the failure of the terrestrial network. This method is considered to be an alternative approach that can improve the performance of the communications network when it is vitally needed.

The scope of this research is divided into the following areas:

- I. A low-altitude platform system was used as an alternative method to enhance the performance of the communication network. The situation demands that portable network nodes be designed for low-level deployment and that the stationary nodes on the ground to be adaptable and functional in harsh environmental conditions.
- II. To reach the desired goals, the methodology used to design the network required the creation of three major network nodes to represent the extended network. Each node was designed for a specific purpose in order to meet the requirements of network deployment.
- III. The installation of communications systems on mobile platforms requires that the factors that hinder their use be identified and addressed. More specifically, the provision of a high degree of stability is required for communication systems installed within the platform. This condition led to the creation of a controller system using the MATLAB environment to determine LoS between the nodes of the network. Moreover, this process provided an opportunity to use free-space optics in the mobile platforms.
- IV. Through the use of the SimMechanics program in the MATLAB environment, dynamic motion was designed to generate the disturbances that

result from the random movements of the L-APs. The purpose of this measurement was to determine and match the performance of the systems effectively.

- V. To verify the atmospheric turbulences that affect the bi-directional FSO, the system was designed by utilizing the “*Optisystem*TM” program to simulate the optical links in the transmission layer.

1.5 Thesis Layout

This thesis consists of six chapters, which are organized as follows:

- I. Chapter 2 presents the important topics and previous studies on the issue of reducing the effects of the disasters. The research and projects that addressed the importance of the use of aerial platforms in several applications led to the realization that they could be particularly beneficial in disaster areas. In addition, the chapter describes the scientific and theoretical concepts that contributed to the design of the control system and bi-directional FSO.
- II. Chapter 3 describes the methodology that was used for the deployment of the communications network in affected areas. The focus of the chapter was concerned with establishing communications platforms as an alternative to the terrestrial network nodes in case of damage or destruction in the network’s infrastructure as a result of the natural disaster. Versions one and two of the smart communication platform system, i.e., SCPSv1 and SCPSv2, respectively, were used to represent the aerial base station. They also represented the main ground unit

(MGU) that would serve as a substitute for any ground stations that were adversely affected by the disaster.

- III. Chapter 4 discusses the design aspects of the communications platform, especially the control system, by utilizing the MATLAB environment. Also, the optical communication system was designed by utilizing “Optisystem” software.
- IV. Chapter 5 presents the measurement results of the bi-directional FSO channel under different weather conditions. In addition, the efficiency of the SCPS-controller system for stabilizing the communication systems was evaluated. Further investigation was conducted in order to ensure the possibility of achieving line-of-sight interaction between the deployed nodes.
- V. Chapter 6 presents the conclusions that resulted from the design and testing of the aerial system, including a summary of the most important ideas, the contributions of this research, and recommendations for future research.

Figure 1.4 below illustrates the flow chart and the measures that have been used to achieve the desired objectives.

Research Process

Smart Communication Platform System For Low Altitude Applications

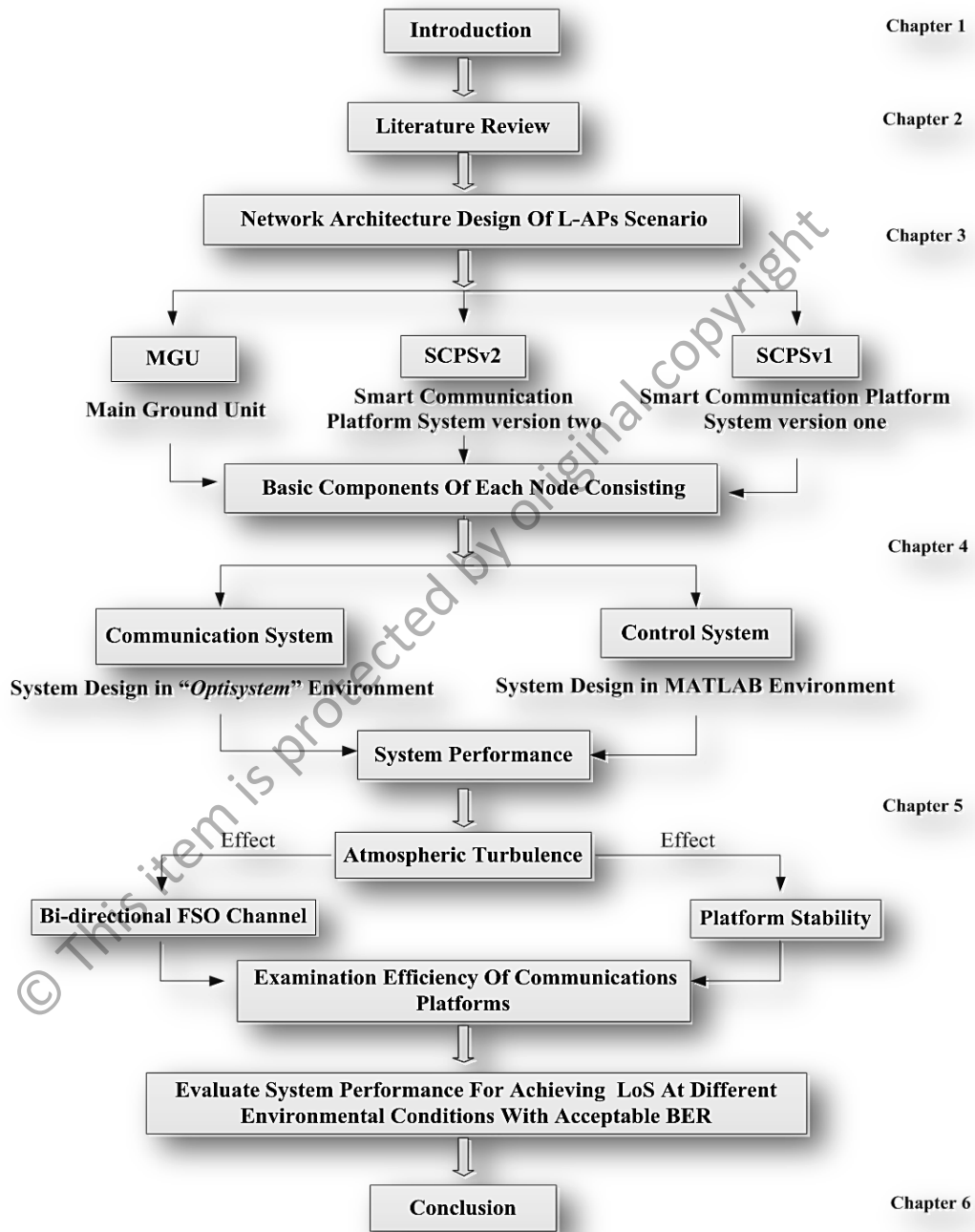


Figure 1.4: Research Process to the Smart Communication Platform System for Low Altitude Applications

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter describes in detail the issue of natural disasters and the negative effects on infrastructure, especially their impact on the structure of the communications network. Also, it explains alternative methods that can be used in the event of damage to the terrestrial network. Low-altitude, aerial platforms can be considered as a substitute for the terrestrial network. Previous studies have indicated the importance of this issue in detail. The use of aerial platforms is accompanied by challenges that hinder the deployment of the communications network. These limitations have been highlighted by introducing projects and previous studies that have used tethered balloons as a means of enhancing the deployment of a communications network in several applications, including areas affected by natural disasters. The second issue that is described is the balloon's payload equipment (communications and surveillance equipment), which is installed inside the platform. In addition, scenarios are discussed that can be utilized to enhance the reliability of data transfer. This chapter also presents the two major themes that are related to the context of this thesis, i.e., 1) the scientific aspects of the optical communication system and 2) the issue of the control system and the theoretical concepts in this area.

2.2 Disaster Situation

The issue of natural disasters recently has become a priority concern for many international organizations, particularly in the Pacific basin areas. The Asia-Pacific regions have significant difficulties with disaster preparedness, response, and recovery (Ure, 2012).

According to Fujiwara et al. (2004), natural disasters, such as earthquakes and floods, entail many negative effects, which, in turn, lead to the destruction of various infrastructures, including telecommunication towers, fiber-optic cables, and the base stations for cellular phones. Here, previous studies on disaster issue and some of the projects that have been implemented are reviewed in order to highlight the importance of reliable communication in these areas.

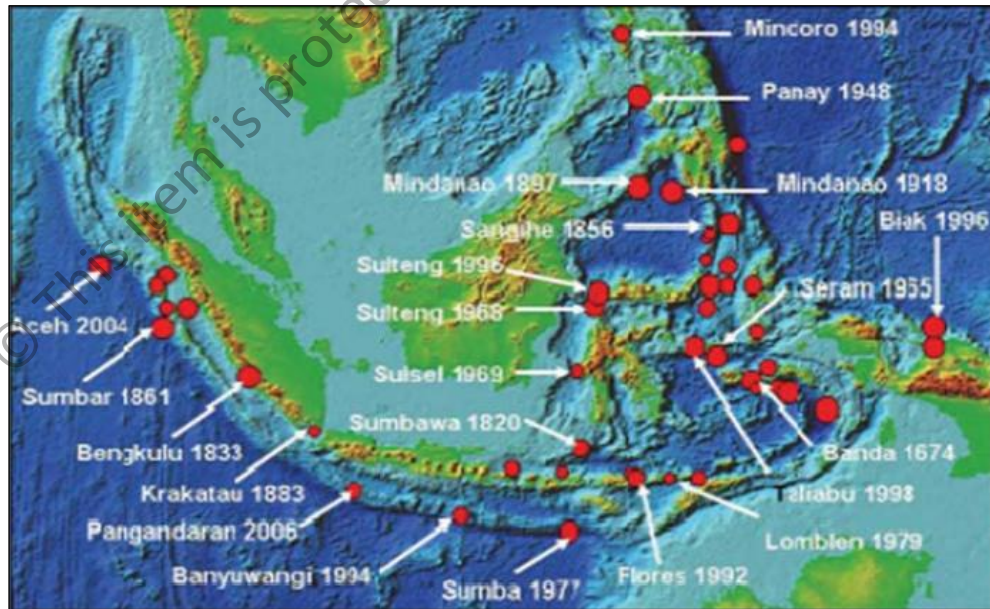


Figure 2.1: Map of Tsunami Disasters in Indonesia (BNPB, 2009)

As a case study, Indonesia suffered many natural disasters during the period of 2004-2007, i.e., the tsunami in Aceh in 2004, the eruption of a volcano and an

earthquake in Jogjakarta in 2006, and the floods in various cities, including Jakarta, in 2007. The effects of these catastrophes destroyed wide areas, including the cities that were near the disaster area. The floods that occurred in Jakarta, the tsunami in Aceh, and the earthquake in Jogjakarta affected most of the service sector in these areas. The infrastructure and telecommunications were damaged or completely destroyed, which made matters even worse by cutting off communications with the affected areas (Hariyanto et al., 2009).

After the disastrous tsunami in December 2004, a complex emergency situation in Indonesia was inevitable. Figure 2.1 shows the occurrences of disasters in 2008 as reported by the Indonesian Disaster Management Coordinating Agency (BNPB, 2009). In 2008, there were more than 300 disasters, including floods, hurricanes, landslides, tidewater events, and earthquakes. The aftermath of these disasters created many serious problems, the most significant of which was the devastating impacts on the populations in the affected areas.

The Global Geospatial-Information Management Organization, which is affiliated with the United Nations, published an article concerning natural disasters and their effects. The effectiveness of efforts to reduce and manage the effects of disasters depends significantly on the efficiency with which the relevant information is used. The significance of sharing data becomes a vitally important issue when disasters occur, when governments must understand the classifications to reduce the damages by taking immediate and appropriate action (United Nations, 2012). Therefore, the focuses are on some of the fundamental issues concerning the issue of disasters and the possible solutions that can be applied to reduce their adverse effects in Indonesia, Japan, and Thailand. There are various reasons for this concentricity, i.e., these countries are susceptible to frequent natural disasters and some manmade disasters, such as the

explosions of the nuclear reactors in Japan. In addition, there are other disasters that have occurred in Thailand. There is significant similarity between the environment in the mentioned areas and the environment and the potential for natural disasters in Malaysia. Thus, these areas provide the opportunity to explore the most important obstacles faced during a disaster and take advantage of their unfortunate experiences. Some investigations have used low-altitude platforms for surveillance and making environmental measurements. The use of aerial platforms for providing emergency response in a disaster area has been promoted because of their ability to deliver easy-to-deploy communication systems. Such platforms can be in the air or grounded, depending on what the mission mandates. However, at the present time, research is still being conducted on the best approaches for designing, deploying, and stabilizing such platforms in order to overcome the obstacles that hinder their effective use.

2.3 Overview of Aerial Platforms

In recent years, aircraft-based telecommunications have attracted significant interest among scientists and researchers. Many types of aerial platforms have been proposed as an alternative approach to the use of satellite wireless networks. According to Tozer & Grace (2001) and Karapantazis & Pavlidou (2005), these aerial platforms are aerostats, evolving at various altitudes, and they are referred to as low-altitude platforms (L-APs) or high altitude platforms (HAPs).

HAPs are a new solution for delivering wireless broadband, and they have been proposed recently for the provision of fixed, mobile services in the stratosphere at altitudes of 17 to 22 km, as shown in Figure 2.2. The broadband communications and applications for high-altitude platforms were discussed by Grace et al. (2001).

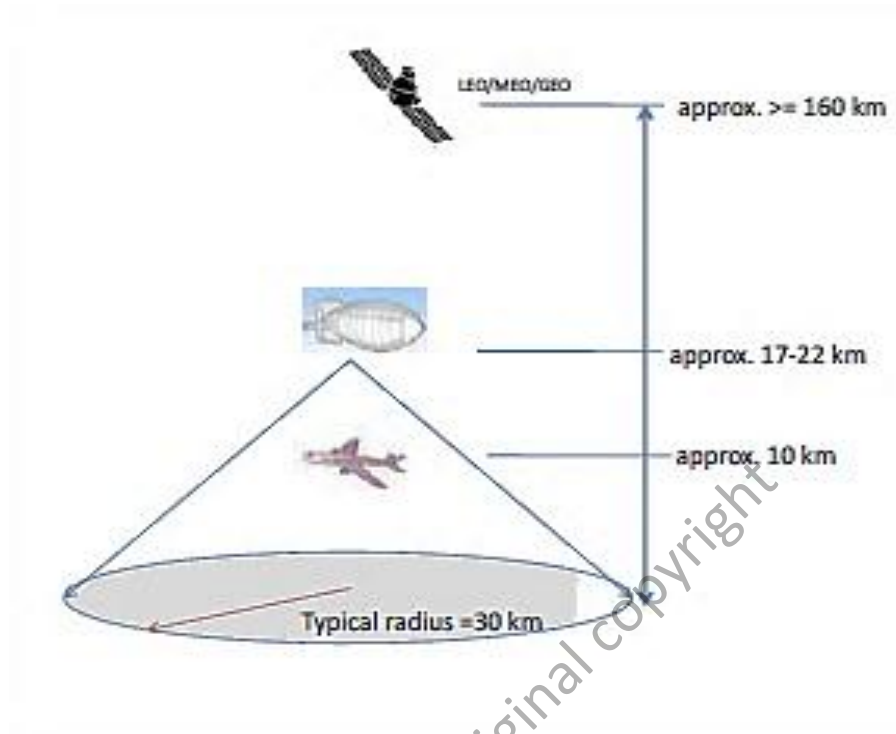


Figure 2.2: HAP System Deployed at approximately 17 – 22 km Above the Ground (Grace et al.,2001)

2.4 Low-Altitude Platforms

Low-altitude platforms can be considered as semi-fixed platforms, such as a helium-filled balloon, which can operate on the ground and at low altitudes of less than 1 km. The focus of the present study is the use of tethered balloons to provide operational communications equipment in disaster areas.

2.4.1 Aerial Photography System

According to Nogami et al. (2002), their research was one of the initial projects that used cameras on low-altitude platforms. In the Space Technology Applications and Research (STAR) program, researchers are looking for a low-cost, light-weight, and easily transportable platform technologies. Several field experiments have been

performed by one of STAR's classes as a part of training in the field of remote sensing. The researchers in the STAR program used three digital cameras to capture color images. The structural design they used was a triangular frame linked with rubber bands and plastic tiers for the camera system. Each camera was fixed to triangular frame by a screw. The observation angles of the different cameras were calculated so that the cameras could take photographs of large areas. Wind drag and the balloon's drifting force were considered because they had a great effect on the camera positioning system.



Figures 2.3: System for Mounting Cameras with Off-Nadir Observation Angles (Nogami et al., 2002)

However, this three-tier, triangular system constantly tended to be aimed straight down toward the ground due to the gravitational force. Since the first tier was linked to the hook near the top of the balloons, it kept the system safe from deviations of the pitch angle. The other two tiers were hooked on the left and right sides of the blimp, which kept the camera system stable from alterations in the roll and yaw angles. Figure 2.3 shows the procedures used to install the camera for remote-sensing purposes. Developments in this field were presented in a study conducted by Eppich et al. (2011), in which an overview was presented of the techniques that are used to design and utilize monitoring platforms.

The advantages of the system are shown in Figure 2.4, i.e., the ability to lift fairly heavy payloads and to serve as a direct substitute for balloon photography, since most of the hardware and software can be used on either system.



Figure 2.4: Remote Control Pan/Tilt Camera Cradle Suspended from a Kite Line (Eppich et al., 2011)

Another unforeseen advantage is that images often can be captured without detection or disruption. Of course, the main disadvantage is that there should be relatively stable winds, ranging up to 4 km/hr. However, in the case of high winds, the experimental results indicated that landing the photographic equipment safely could be difficult. Other disadvantages have been identified when the wind speed increases to 30 km/hr. Therefore, controlling the system at such high wind speeds is a challenge.

2.4.2 Aerial Communication System

According to Lee (2005), wireless equipment and various antenna attached to helium-filled balloons have been used. The methodology was applied by utilizing an airship, allowing the sending and receiving of video, audio, and digital information. Thus, balloons have played an important role in connecting networks so that

information could be sent and received, assisting users in making strategic decisions in emergency situations. Figure 2.5 shows the platform payload attached to a balloon.



Figure 2.5: Communications Equipment Payload Attached to a Balloon (Lee, 2005)

The function of the balloon and its payload is to support the users of the communications network when the ground units are no longer operable due to a disaster or some other event. This gives users the ability to analyze the situation and take appropriate action based on the information sent from the other network nodes. Helium-filled balloons provide an inexpensive solution for maintaining the visual, audio, and sensory information required to conduct tactical operations. However, many environmental conditions must be addressed before a tethered balloon system can be operated in an all-weather climate. Wind speed is an especially important consideration because it can have a significant effect on the performance of the balloon. Thus, the balloon must have a certain degree of stability to reduce fluctuations in the position of the platform. The tension of the balloon system's tether and winch hardware is affected by high wind speeds. Wind-flow patterns have the most influence on the system's

connectivity potential. When fluctuations in the balloon's position occur as a result of changes in wind direction, the ability to access wireless signals from the balloon payload are immediately and adversely affected. Tethered balloons do not have the capability of maintaining a stable state during flight. The speed and position of the balloon change depending on wind direction. This characteristic makes predicting connectivity strength difficult at best.

According to Suzuki et al. (2006), communication systems that utilized balloons that were 50-100 m above the ground were suggested to enhance the communication backbone in disasters. The experiments were performed by four balloons on the campus of Niigata University. The wind was strong and was subject to change during the test because of the site was near the coast. Furthermore, the balloon changed direction depending on the direction of the wind. The quality of the channels changed rapidly due to the balloon's erratic flight.

The communications equipment was placed inside the box that was suspended from the bottom of the balloon to represent a sky communications node. This node was composed of a mini-computer with two LAN (WLAN) wireless card devices. An omnidirectional antenna for WLAN was located outside the box that held the communication equipment. Figure 2.6 shows the communication platform that was used in this experiment, and Table 2.1 provides the specifications for the communication devices.

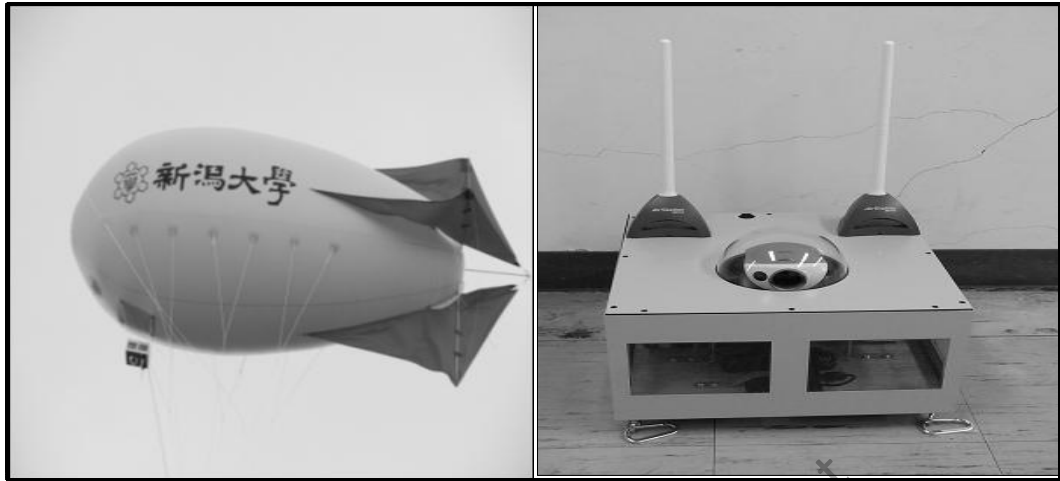


Figure 2.6: Equipment Box Hanging Upside Down from the Balloon
(Suzuki et al., 2006)

Table 2.1: Specifications of Platform Equipment (Suzuki et al., 2006)

Equipment	Specification
Mini Computer	Plat 'Home OpenBlockS266
WLAN NEC	WL54AG(802.11g)
WLAN Antenna	Buffalo WLE-HG-NDR
Network Camera	AXIS 213 PTZ
GPS Receiver	GARMIN Geko301

Preliminary results of the experiments confirmed that the alternative communications network can be built quickly. Also, it can be used to enhance performance in an emergency situation in which the terrestrial communications infrastructure is incapable of carrying out its functions. According to Bilaye et al. (2008), the authors have proposed low-cost, wireless Internet access using aerostat ts. There is an urgent need to bring the rural areas into the mainstream by providing them the last component required for connectivity, especially during natural disasters, when

other means of communication are severely hampered. Figure 2.7 shows the conceptual design of the overall system.

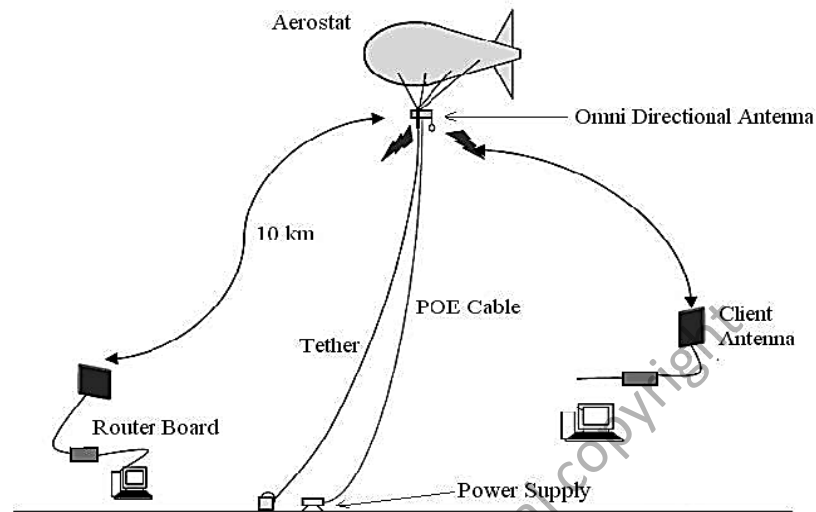


Figure 2.7: Conceptual Design of the Overall System (Bilaye et al., 2008)

The study demonstrated low cost innovative solutions to provide Internet access to rural areas using tethered aerostats. The proposed system, which would have a central base village from which Internet connectivity could be provided to neighboring villages, has been studied extensively to determine its technical and economic feasibility. The use of aerostats results in a reduction in the overall cost of the system. Setting up of several point-to-point links will certainly distribute the available bandwidth by using Wi-Fi with a point-to-multipoint setup being a feasible solution. The proposed system also can be deployed immediately to provide service when emergency situations occur, such as floods, earthquakes, and other natural disasters that affect areas where connectivity is the worst. The primary technology used for building low-cost wireless network belongs to the 802.11x family of protocols, also known as Wi-Fi. The researchers have been using the following method to connect the network nodes. The Wi-Fi link was set up between one access points (AP) configured in infrastructure mode, and two clients were placed at an approximate distance of 1.2 km from the AP.