Mapping Approach for True Internet Protocol Geo-location Information using Active and Passive Methods

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Dedication

I dedicate this hardworking effort to my respectable parents, teachers, friends, and family members who have always been a source of inspiration, encouragement, and great ideas for me. This dedication includes all marketers, service providers, and law-enforcement agencies who are, one way or the other, a part of the circle related to IP to Geolocation. With honour and respect, I dedicate this work to all the researchers and knowledge seekers, hoping that this work will contribute to any future study getting a hold of this topic. The system described in this report is developed and deployed internally at CRC-BU, and will be an active service provider after this project's conclusion.

Muhammad Azam

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Contents

List of Figures

List of Tables

Abstract

The geolocation information refers to an Internet Protocol (IP) address which is useful for several Internet applications such as cyber security analysis, content delivery, product advertising, fraud detection, and prevention approaches. IP to geo-location mapping requires landmarks values to locate a user IP that conceals its geo-location (latitude longitude). The mapping approach for true IP to geo-location plays a vital role in the protection of databases and software systems-based applications. The accuracy performance of such mapping approaches is directly impacted by delay-distance relations and limited visible landmarks among network entities. Several approaches and mathematical models have been designed to overcome these issues such as trace route, ping, and landmarks. Due to the dynamic nature of the internet, many issues have been observed like weak connectivity, congestion, and delays. Achieving high accuracy in IP location mapping is an uphill task. GeoCAM is a recent approach to finding the real IP to geo-location with maximum accuracy and to finding the delay relation between the target and landmarks. However, accuracy, reliability, and latency can be further improved based on the last route between Target IP and landmarks. This research proposes a multi-measurement (passive active) framework that uses the Last Router Geo-location (LRG) and filtration shortlisting algorithm. Closed-Circuit Televisions (CCTVs) landmarks are used as a high-quality landmark. The proposed framework identifies the exact location of the target by locating the landmarks based on delay distance conversions. Extensive simulation experiments are conducted to find the precise location of a target IP with higher accuracy and reliability. The accuracy of the LRG framework is improved from 94.20 % to 96 % using passive and active approaches.

Abbreviations

ICANN Internet Corporation for Assigned Names and Numbers
ARIN American Registry for Internet Numbers
IANA Internet Assigned Number Authority
RIR Regional Internet Registry
NIR National Internet Registry
LIR Local Internet Registry
ISP Internet Service Provider
LACNIC Latin American and Caribbean Internet Addresses Registry
RIPE NCC Réseaux IP Européens Network Coordination Centre
AFRINIC African Network Information Center
APNIC Asia Pacific Network Information Centre
PTCL Pakistan Telecommunication Company Limited

Chapter 1

INTRODUCTION

1.1 Overview

This chapter presents the introduction of Internet Protocol (IP) to geo-location and its usage towards wired and wireless networks. Chapter 1 also covers the impacts of IP to geo-location on Internet applications, problem background, problem statement, research questions, research objectives and study scope regourously. Chapter concludes with thesis organization and contents details.

An Internet Protocol (IP) address is a number assigned to devices that are connected over the network. Routing over the internet is primarily managed through the destination IP address. Users/devices can conceal their IP address to remain anonymous over the internet using proxies or virtual private networks. True IP refers to a non-concealed IP address. IP to geo-location means to find the location (latitude longitude) of devices based on their IP addresses [1] The companies are used location information for advertisement and online shopping centers to stream their platforms [2]. The major applications of IP to geo-location are online fraud detection, content delivery services, language selection, content personalization, network attack trace back, and target tracking by law enforcement agencies [3]. In emerging domains, the IP to geo-location information must be known for many Internet of things (IoT) applications to determine illegitimate devices. Confidentiality and integrity are the main pillars for end users but in some cases, it is essential to find out the true location of a user. Finding the location of devices is considered a critical aspect to ensure security and privacy for law enforcement agencies. Some important IP to geo-location applications are

1. **Fraud Detection:** to locate malicious users who perform criminal activities over the internet or network.

2. **Geo Targeting:** to detect a website user location to serve location-based content or advertisements.

3. **Geo Fencing:** to engage users by sending them relevant interesting emails or messages.

4. **Geo Tagging:** to enable users to find media or files based on location.

Internet Assigned Number Authority (IANA) allocates IP addresses globally to identify or describe the user's actual physical location. IANA is categorized into five registries named LACNIC, ARIN, RIPE NCC, AFRINIC, and APNIC. For example, APNIC consists of 56 countries in the Asia Pacific including Pakistan, China, and India. All these registries are termed Regional Internet Registries (RIR's). These registries maintain databases of the IP addresses and their allocation information. The database is termed as WHOIS database [4]. In a region, each country has its Internet Service Providers (ISP) Pakistan Telecommunication Company Limited (PTCL) assigns IP addresses to RIR's, and further these registries provide IP addresses to end users [5]. Media Access Control (MAC) addresses are unique identifiers for network interfaces on devices to identify the devices. The basic objectives of MAC address locating and tracking the devices in the network. MAC address can be accessed at one hop location and IANA only allocates geo-location to IP addresses. Figure 1.1 shows the IP address allocation to end users by IANA.

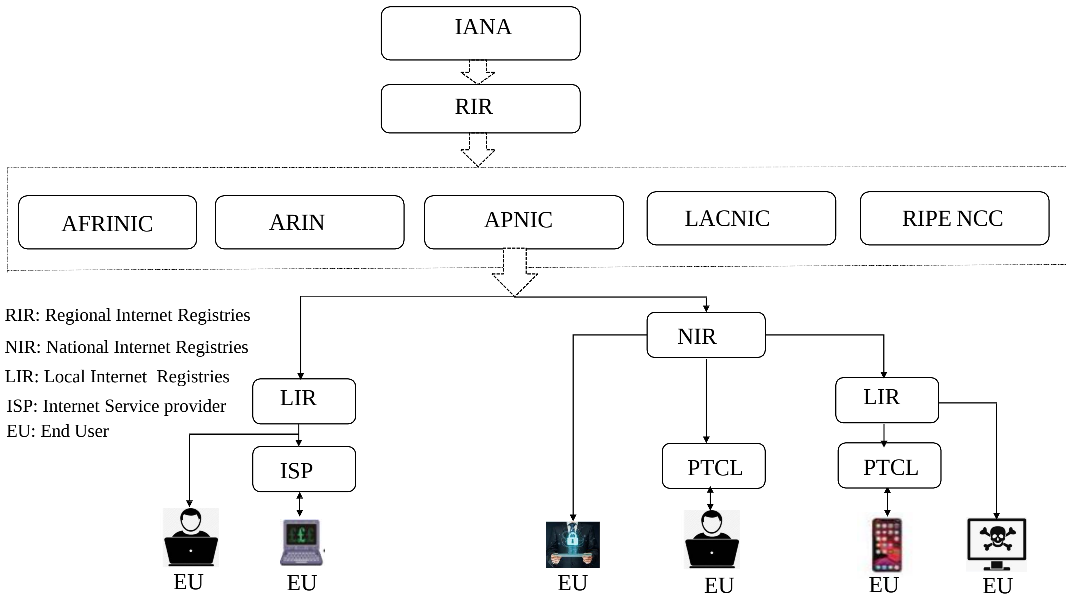


Figure 1.1: IP SPACE Allocation by IANA

Following the aimed accuracy for internet users, IP to geo-location information is categorized as follows: Country-Level Geo-location, City-Level Geo-location (CLG), and Street-Level Geo¬location (SLG). City-level geo-location includes city-level coordinates and street-level geo-location is derived from city-level coordinates.

Internet users try to hide their locations due to the following reasons.

1. **Detection Avoidance**:

   Malicious users do not want their acts to be traced by automated systems, which may be used to prove their wrongdoings due to geo-location inconsistencies.

2. **Prosecution Avoidance**:

   Fraudsters and other cyber criminals can disrupt the efforts of law enforcement agencies by showing false locations.

3. **Marketing**:

   In regions where their actual servers are not present, Virtual Private Network (VPN) providers tend to sell their services.

1.2 Geo-location approaches

Two main geo-location approaches for finding IP locations are referred to as active and passive. An active approach is based on network measurement methods while a passive approach uses available IANA or other IP to geo-location databases.

1.2.1 Passive geo-location

1. 1. Determine location by analyzing available data on websites, social platforms, and mobile Apps [4].

2. 2. Determine exact user geo-location using single or multiple IP location databases [5].

3. Although passive approaches can quickly resolve the location but due to dynamic nature of IP allocation, entries in such databases might be incomplete or stale.3. Although passive approaches can quickly resolve the location due to the dynamic nature of IP allocation, entries in such databases might be incomplete or stale.

Figure 1.2 provides information about 111.68.99.9 located in Bahria University through online database named as **whatismyipaddress.com**.

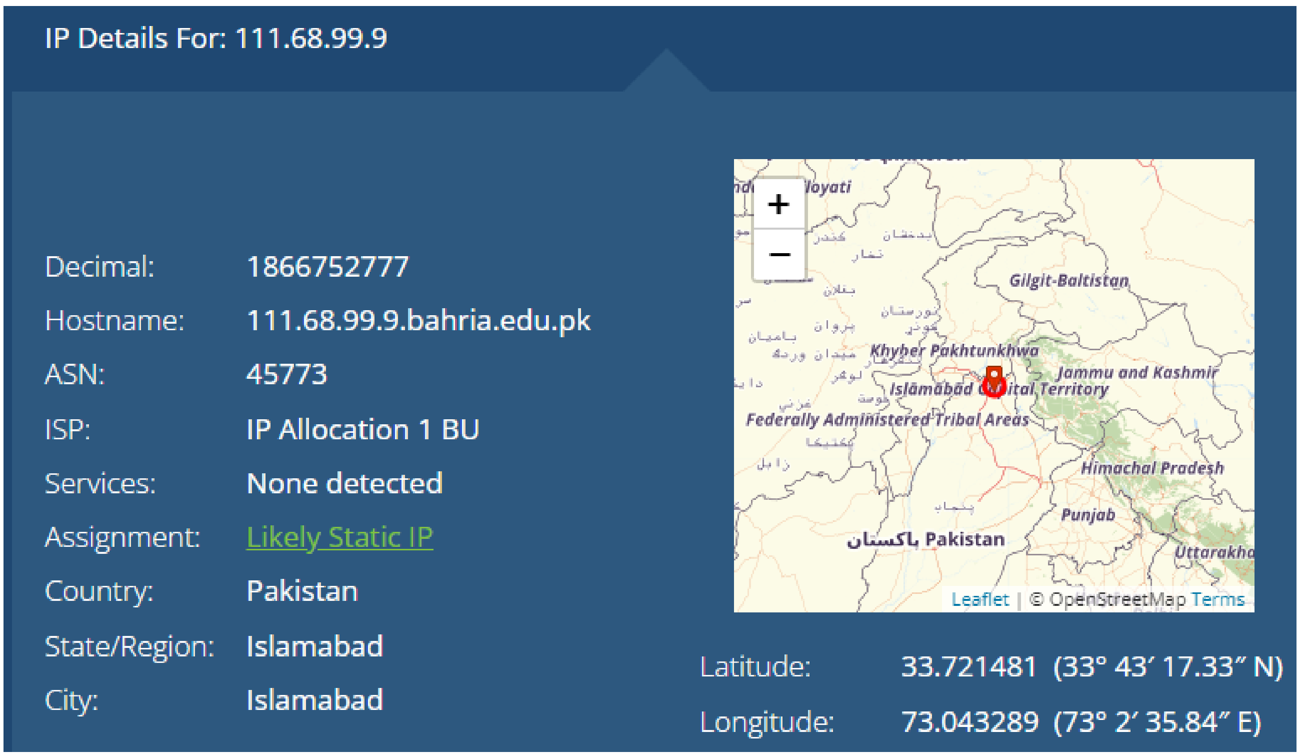


Figure 1.2: IP to geo-location mapping - whatismyipaddress.com

The Passive geo-location approach finds the user's location without using any network measurement tool. Using the IP mapping-based approach is a passive geo-location method, as it does not interact with the target. Instead, queries are placed based on publically available Regional Internet Registries (RIRs), Domain Name System (DNS) locality records, WHOIS lookups, and commercial geo-databases [1, 6, 5, 7]. The following approaches are considered passive geo-location approaches to find the locations of the devices over the network.

1. 1. Data-driven approach.

2. 2. DNS Records

3. 3. WHOIS Databases, regex hostname.

4. 4. RIR, geo-location databases (DBs) (Commercial)

In the passive geo-location approach, the majority of internet data focuses on locating the IP infrastructure rather than addressing a particular device. Some APIs make use of Regional Internet Registries (RIR) [8], which store data on servers and make it accessible to the public for good understanding. The databases of regional registries, such as APNIC, RIPE NCC, and others, contain the following records for all IP addresses [9]:

1. Contact information.
2. Routing policy information details.
3. Autonomous System Number assignment.
4. Allocation and assignment of IP Addresses.
5. Record of reverse DNS registration.

The registry databases search in different ways, including web interface, command line interface, and restful APIs. The information is kept in the form of objects. Each object possesses several attributes and is used for storing data values. These databases also provide different search formats such as using a lookup key or primary key or using advanced search options present in the web interface. Each regional database stores the complete information about the IP address of their regions. Along with the regional data, these databases also work collaboratively by mirroring other registry databases. The mirror database excludes in-depth information such as IP address's contact information, while searching the mirror database, the results show that IP is assigned to a specific region. More information about that specific IP allocation will be available for its regional database. Apart from regional databases, commercial databases such as MaxMind, IP2Location, NetAcuity, IP to geo-location, and Quova are also available online and offer IP Lookup functionality.

Figure 1.3 shows the result from the RIPE database, but it does not give information about the latitude and longitude of the IP address.

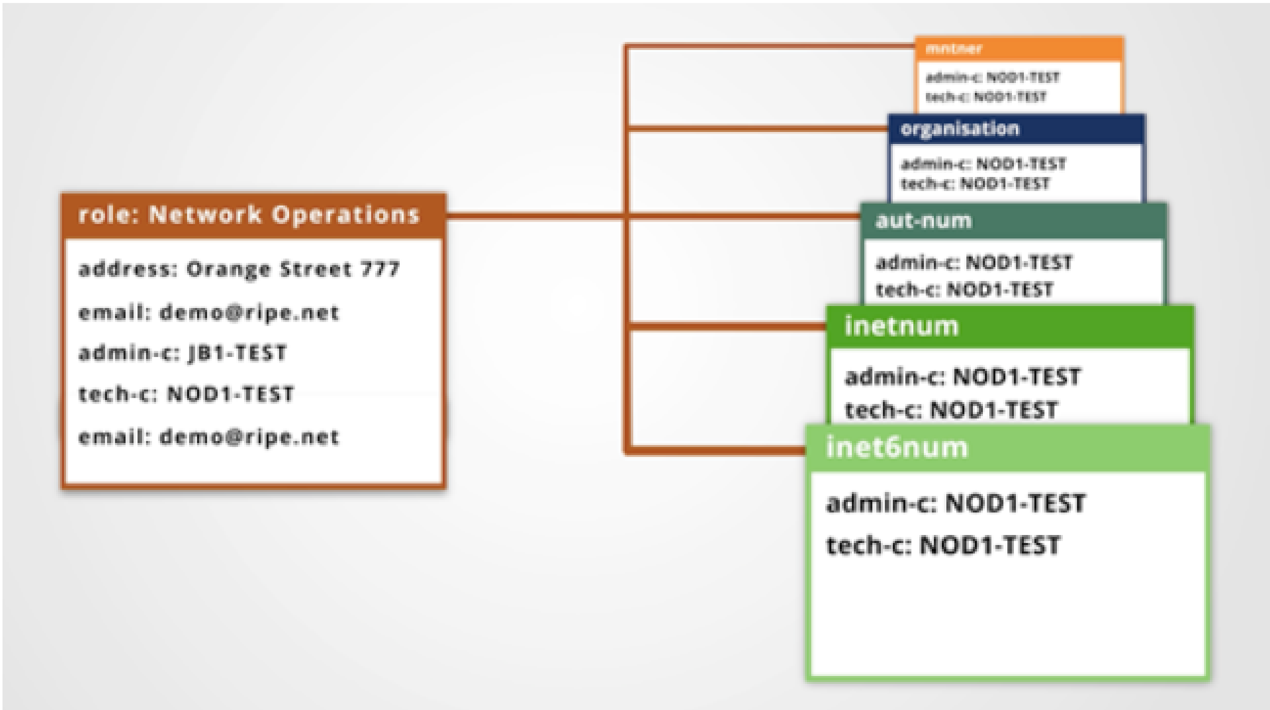
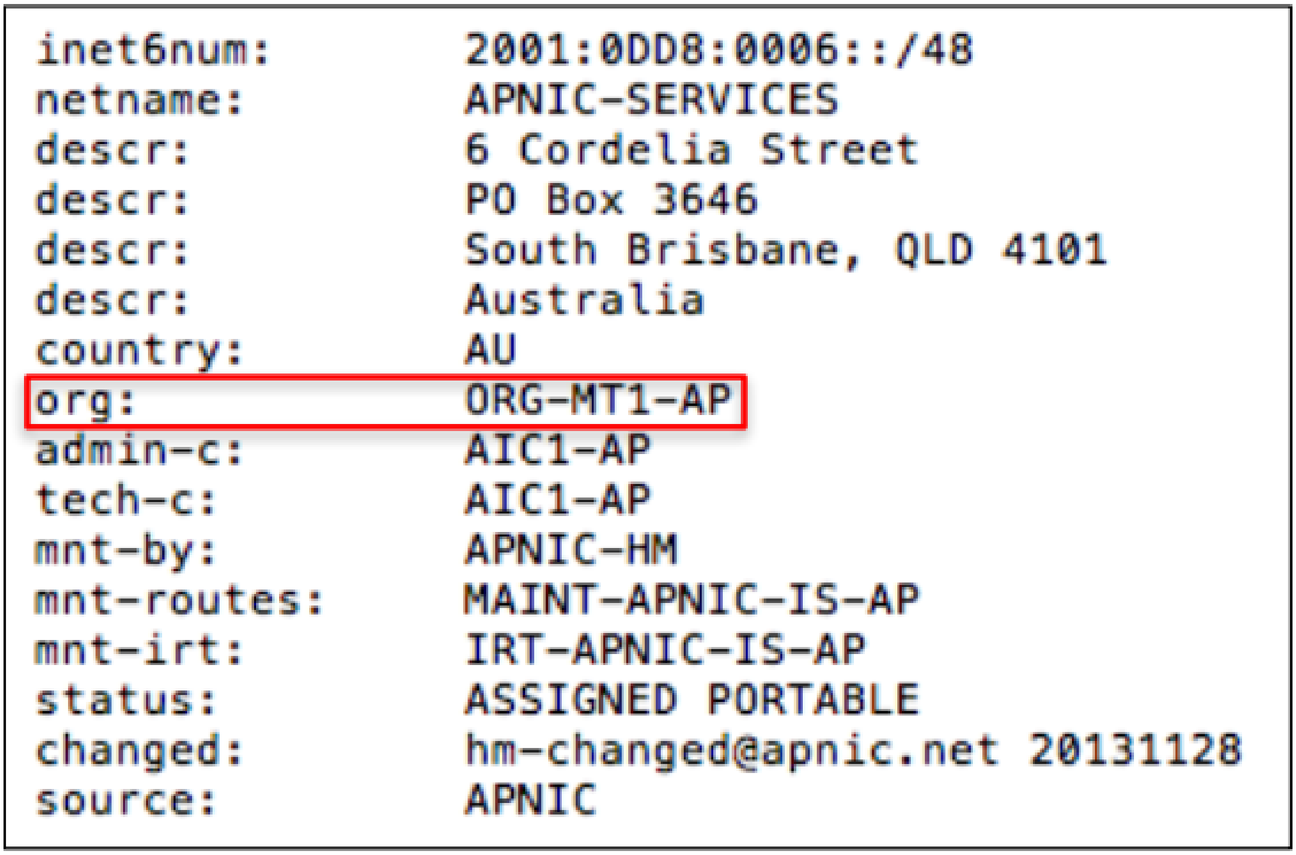


Figure 1.3: Sample Results for RIPE Database using Passive Approach

On the other hand, another RIR, APNIC provides broad location information that cannot be mapped to precise latitude and longitude, as shown in Figure 1.4.



```
inet6num:       2001:0DD8:0006::/48
netname:        APNIC-SERVICES
descr:          6 Cordelia Street
descr:          PO Box 3646
descr:          South Brisbane, QLD 4101
descr:          Australia
country:        AU
org:            ORG-MT1-AP
admin-c:        AIC1-AP
tech-c:         AIC1-AP
mnt-by:         APNIC-HM
mnt-routes:     MAINT-APNIC-IS-AP
mnt-irt:        IRT-APNIC-IS-AP
status:         ASSIGNED PORTABLE
changed:        hm-changed@apnic.net 20131128
source:         APNIC
```

Figure 1.4: Sample results for APNIC Database using Passive Approach

1.2.2 Active geo-location

Active IP to geo-location is a network measurement-based approach that performs latency measurements to find the exact user's physical location [10], It consists of the following terminologies.

1. **Target**: The host who is going to be traced.
2. **Landmarks**: A host having a known IP address and location
3. **Probe Point**: A monitor from where a target is being traced.

The active geo-location approach consists of four phases. In the first phase, the nearest probe to the targeted IP address is located on a topology basis. And then multiple pings are selected from the probe point to the target. In the second phase, RTT measurements of all the ping results are taken, and eliminate the values above 10ms. Because there may be a chance of numerous nodes between hosts and the destination, therefore there is a possibility that data packet passes through these nodes and provides output in high Round Trip Time (RTT). Now, One-Way Delay (OWD) is determined from RTT/2. In the third phase, latencies with minimum values are transformed into physical distances. In the fourth step, the geographical distances are grouped in the form of a circle, with the user's precise IP address at the center. Moreover, 100 cities are chosen inside the circle. The city with the least latency value between the circles is then returned as output and displayed to the user as result.

1.3 Network Delays

To understand the active geo-location approach, it is crucial to consider network delays. A Detailed Path-delay framework for Router geo-location [11, 12] provides a useful mechanism for considering the time taken for one host to reach other over the internet. During internet communication, a data packet travels via several in-between routers (informally known as "hops"), each linked with a connection (ordinarily, an optical fiber link). During the packet's traveling, there may be several delays. Some are necessary and predictable, while others are more difficult to identify. In this mechanism, there are four basic types of delays:

1. **Queuing Delay**

   The delay in processing packets in a queue before they are sent to a router is called queuing delay. According to this type of delay, the incoming packet rate, the transmission capacity of the outgoing link, and the network traffic type are determined.

2. **Processing Delay**

   This is the time when the router takes to scan the header and decide what to do with the packet. It is usually a very small delay, except for when the router is encrypting packets or inspecting them.

3. **Transmission Delay**

   Time, the router transmits the packet's bits to the destination. Transmittal delay is directly proportional to the packet size and also to link speed (data rate). It is sometimes referred to as a store-and-forward delay.

4. **Propagation Delay**

   It is the time when packets cross the link from one side to the other. This delay is proportional to the length of the link.

Mostly, random fluctuation in delay measurement is due to queuing and processing delays. Each hop in the packet's journey is affected by queuing and processing delays, the greater the random fluctuation in delay measurements will be as the number of hops increases. In geo-location, propagation delay is the most important type of delay, because it is proportional to the distance between two hops, or the length of the link. Therefore, the link delay between hosts A and B is proportional to the sum of the propagation delays between the two hosts.

1.4 Measurement Tools

Two measurement tools named ping and traceroute are used for the active geo-location approach.

1. **Ping**

   A ping is a method of determining how long it takes for one host to communicate with another host via the internet. Internet Control Message Protocol (ICMP) echo requests are normally measured by sending a packet and counting the time between the sending host and receiving host's response.

2. **Trace route**

   A traceroute records the intermediate routers (also known as hops, as explained above) from where packets travel on their way from host A to host B. These hops' delays are also saved. A common way of achieving this is to send ICMP echo request packets with increasing Time-to-live (TTL) values. When a TTL of n is applied to a packet, the n'th hop returns an ICMP error message. The n'th hop can be determined by sending an ICMP echo packet with TTL n and checking the source IP address provided in the ICMP error message received. The last hop responds with a typical ICMP Echo response, allowing the traceroute to be completed. Figure 1.5 shows the overall method.

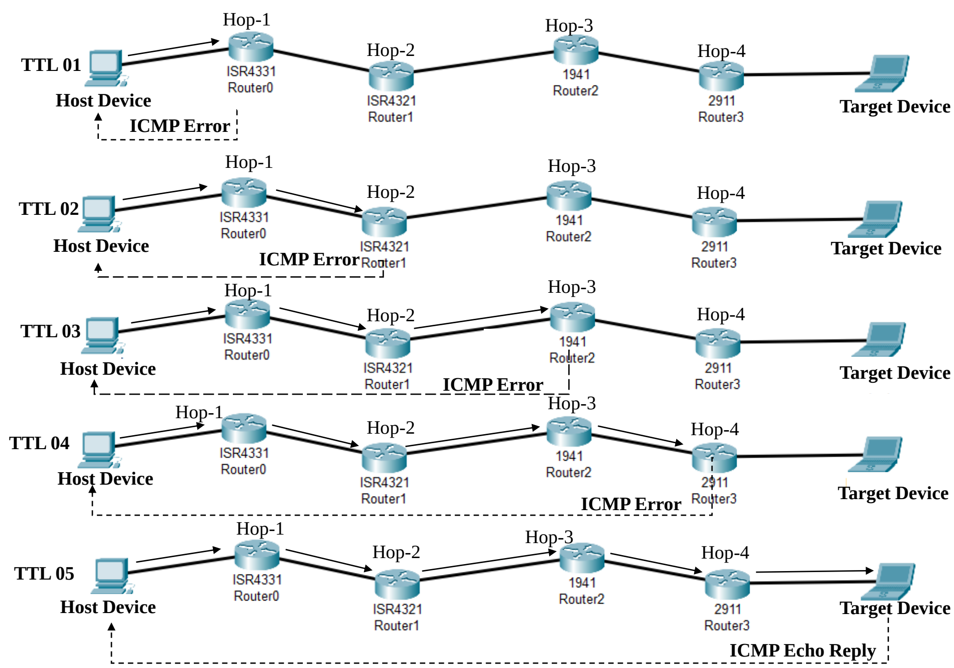


Figure 1.5: Trace Route Method

To locate the exact location of a user, measurement-driven approaches such as ping and trace routes are used.

1. **Trace route**:

   To trace intermediate routers to target [7].

2. **Ping**:

   To find latency between one host and another [10].

3. **Nearest Neighbors**:

   Using the location of the landmark with the lowest latency ("nearest neighbors") as the location of the users, the latency measured between many landmarks and the target is measured [13].

4. **Multilateration**:

   As part of this method, ping measurements are used to measure latency towards a target from many different locations, and then these measurements are used to find "feasible regions" in which the target can reside [14].

1.5 Problem Background

Internet Assigned Number Authority (IANA) allocates IP addresses associated with geo-locations globally and is primarily used for routing over the Internet. The world is divided into five registries according to IANA named LACNIC, ARIN, RIPE NCC, AFRINIC, and APNIC. For example, APNIC consists of 56 countries in the Asia Pacific including Pakistan, China, and India. These registries are collectively known as Regional Internet Registries (RIR's). Databases of IP addresses and their associated allocations are maintained by these registries. This database is known as the WHOIS database [14].

In emerging domains for many Internet applications [3], the IP to geo-location information must be known, to determine illegitimate devices. There are some cases where users/devices can conceal their IP addresses to hide their actual location due to: (i) malicious users do not want their actions to be traced by automated systems, (ii) in prosecution avoidance, the fraudsters, and other cyber criminals can disrupt the efforts of law enforcement agencies by showing false locations on websites, (iii) To achieve marketing targets in various regions, where their actual servers are not present, VPN providers tend to sell their services. Further, cyber security is greatly influenced by mapping methods for true IP geolocation. The number of software systems applications and databases is increasing day by day compared to the number of physical entities. For example, a large portion of most industries is dependent on internet services and computer-based technologies. Using IP for Geo-location in today's world is modern technology and the Internet is only one possible application. IP to Geo-locating mapping approach can assist us to identify and locate such bad actors from the network. This is a simple example of how IP to geo-location approaches can be beneficial in today's technological age.

Passive and active approaches are used to find IP to geo-locations mapping. A passive approach determines IP-to-geo location by analyzing available existing IANA information on websites, social platforms, and mobile apps [4]. Although this approach can identify the location due to the dynamic nature of IP allocation, entries in such databases might be incomplete or stale [5]. However, the performance of the passive approach is limited as it only focuses on locating IP infrastructure, rather than addressing specific devices.

Active IP to geo-location approach involves these major measurements to find the exact user physical location: (i) trace route between intermediate routers to target device [7], (ii) find latency between one host to other devices [10], (iii) using the location of the landmark with the lowest latency ("nearest neighbors"), the latency measured between several landmarks [13], and (iv) Multilateration used to find "feasible regions" in which the target can reside [14]. Several studies have been conducted to improve the performance of existing IP to geo-location approaches. In addition, earlier studies highlighted the importance of a high number of landmarks for better IP to geo-location mapping. To the best of our knowledge, GeoCAM [7], IP to geo-location mapping approach uses landmarks as global data to find a better physical location of the target device. The GeoCAM approach monitors websites with webcams or CCTV cameras regularly, whereas IP addresses are retrieved based on Natural Language Processing (NLP) techniques using webcam latitude and longitude information. In GeoCAM, the target host is identified by first identifying the region it is located based on delay distance. Based on these distances, the fine region is identified. In that fine region, landmarks are selected by removing those that are not relevant to the target. After that, based on the landmarks selection, Multilateration is performed to locate the target IP. The accuracy of the GeoCAM approach is affected by the selection of landmarks due to network topology constraints.

Although, the accuracy of true IP location mapping using IP camera-based landmarks for existing studies have been reached 94.20 % [7] However, the performance of IP to geo-location approaches still can be improved in terms of accuracy, latency, and reliability.

1.6 Problem Statement

The mapping approach for true IP to geo-location plays a vital role in cyber security. Nowadays, databases and software systems are more important than physical entities. For example, the banking industry is heavily dependent on internet services and other software-based technologies. A cyber-attack can be disastrous for an IP-based business. IP to geo-location mapping can assist us to identify and locate such bad actors from the network. Existing literature [5], [5] complement the use of multiple measurement frameworks for determining IP to geo-location, as a single method cannot provide a high degree of accuracy. Due to the dynamic nature of internet congestion, weak connectivity, and delays; achieving a high degree of accuracy in IP location mapping is an uphill task. Recent literature [5], [7]has used trace routes, ping, landmarks, and different mathematical models for the said objective. The accuracy claims for IP to geo-location are improving and true IP location mapping using IP camera-based landmarks has reached 94.20 % accuracy [7]. However, the accuracy, reliability, and latency of IP to geo-location mapping techniques can be further improved.

1.7 Research Questions

The research questions of this study are as follows:

1. How to determine the exact IP Geo-location information for illegitimate users?
2. How to map true IP Geo-location information aimed with high accuracy?

1.8 Research Objectives

The main research objective is to design and develop an IP-to-geo-location mapping technique to achieve a higher degree of accuracy. To achieve the said objective, the multi-measurement framework will be used with the following objectives:

1. To determine the exact IP Geo-location information for illegitimate users by using the active method.

   (a) Use of quality landmarks to increase the accuracy of the target location

   (b) The traceroute uses to find the last router for landmarks and target IP

   (c) Multilateration uses to find the intersection of distances between the last router and landmarks

2. To map true IP Geo-location information aimed with high accuracy by using active and passive methods.

   (a) Delay always occurs due to weak network connectivity or congestion. Further, Accuracy has been obtained based on the delay-distance relationship.

1.9 Thesis Organization

The remaining thesis is structured as follows: Chapter 2 discusses existing methods through a detailed literature review. Chapter 3 explains the detailed research methodology. Chapter 4 presents the analysis and the results of the research methodology. Chapter 5 ends with the conclusions, along with future research goals.

Chapter 2

Literature Review

2.1 Overview

This chapter discusses in detailed IP to geo-location mapping approaches (active and passive), a set of used or utilized databases, various existing methodologies, technologies and standards. Chapter 2 also describes a detail literature review to highlight the existing issues and challenges in IP to geo-location mapping approaches. Achieving high accuracy tasks in IP to geo-location mapping issues are also elaborated in detail aimed to design an efficient mapping approach to find the precise location of a target IP with higher accuracy and reliability. Table 2.1 shows a summary of different existing studies in term of main concerns to address, associated used work, evaluations metrics, limitations and improvements.

IP to geo-location mapping is described using a variety of approaches named passive or active approaches. The passive approach makes use of mapping databases collected from various regulatory authorities such as ICANN. While active approach, on the other hand, accomplishes the same objectives by utilizing parameters such as landmarks, ping latency, and traceroute. Figure 2.1 shows the different approaches for locating an IP address.

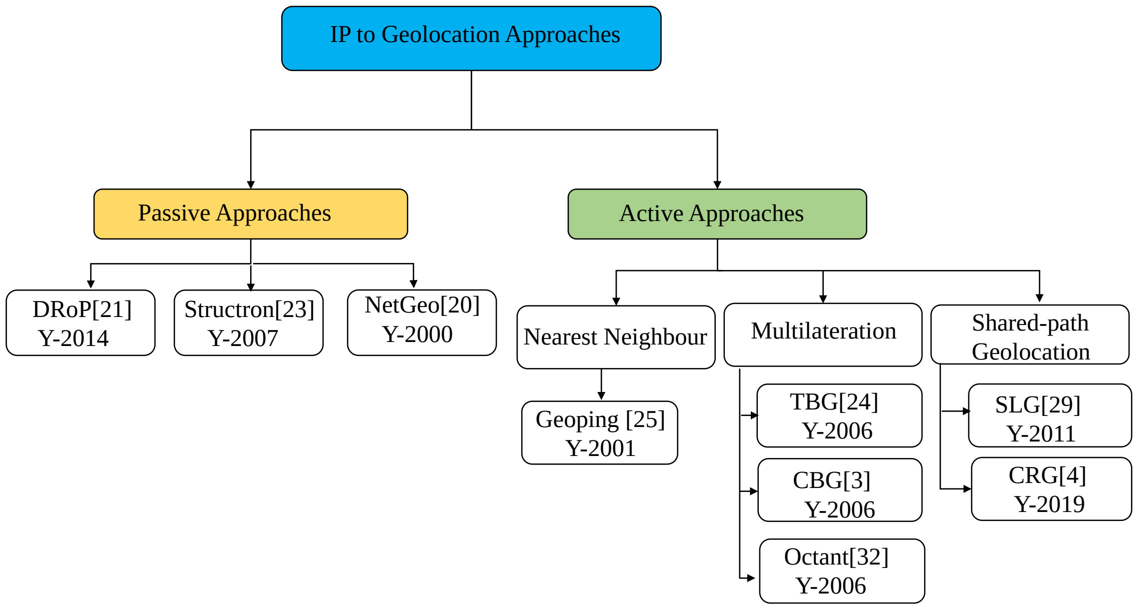


Figure 2.1: IP to geo-location approaches

2.2 Passive geo-location

Back in 2000, the passive geo-location approach is used named as NetGeo [15]. NetGeo worked as a mapping tool that mapped Internet Protocol (IP) addresses, host names, and Autonomous System Numbers (ASN) to get geo-location information of the user. Cooperative Association for Internet Data Analysis (CAIDA) no longer managed, so it is no longer operational. The public entered IP addresses and retrieved location information obtained from the mapping database. NetGeo mapping focused on two approaches: hostname regexes and WHOIS registration record queries. Due to NetGeo's passive nature, it can retrieve geo-location information quickly. Writing regex rules manually consumes time. As a result, NetGeo is not effectively maintained. DRoP [16] and the Undns utility [17] both expanded the idea of establishing the regex rules for host names. Structon [18], is another passive geo-location approach. Structon is a web mining technology that extracted location-based data from web pages. Methods such as "Addr:" and "Zipcode" are utilized to find the IP addresses. The IP address hosting the web page is mapped to the obtained location of these addresses. A mapping record of IP address locations is built in this manner.

In [18], authors concluded research where the Internet's structure was found to be significantly different. AWS is introduced in 2006, and during that time, a lot of locally hosted websites are presented. According to State of Net craft, the number of websites hosted by AWS increased from around 100K to over 10 million between 2009 and 2013. This issue increases in speed, which is developed to the extent that most businesses now used hosting services to host their websites. Because Stratton approach involves hosting websites in data centers that are located far from the actual business. An issue is raised because most of the website location information appeared inaccurate [18].

2.3 Active geo-location

To find the exact location information of a user, active geo-location algorithms use measurement methods like traceroute and ping. Active geo-location algorithms are termed "network measurement-driven" algorithms in the literature. The organizations looking to find the exact location of the devices/end-user have a monitor or collection of monitors. A monitor/system is a probe point used to take the measurements, where a probe point is any device connected to the internet with a known location from which measurements can be taken using ping or traceroute.

2.3.1 Nearest Neighbours

A basic active geo-location method is involved to measure the delay between a vantage point and the target point, then selecting the landmark with the lowest latency as the shortest ping to its location, and using that position as the target's location as used in [13]. However, this method is efficient if the vantage point is located close to the target. A vast number of vantage points would be required to find geo-location information of users with the geo-location method. GeoPing used in [19], provided more information to entail the pinging landmarks from several vantage points and recording a 'latency vector' for each landmark the same way, a latency vector for locating the target IP is required. GeoPing used in [19], provided a modification of the nearest neighbors method. Vantage points are used to ping a collection of landmarks and a "latency vector". A vector [D0... DN] is recorded for each landmark, where Dn refers to the latency reported by the k'th monitor. After identifying the "nearest neighbor" of the target's latency vector, the landmark distance vector with the shortest Euclidean distance to the vector is found. By using the nearest neighbor distance vector, the host's location is determined. The GeoPing method is very easy and efficient, hence it is commonly used. The majority of researchers have used it as a benchmark to compare it with other algorithms. However, there are still limitations in this method, as it requires a large number of landmarks to achieve optimal accuracy. GeoPing has an inaccuracy even in the best-case scenario. Figure 202 shows the example of Nearest Neighbours using monitors in the UK, Italy, and Belarus.

2.3.2 Multilateration

In this method, the target is traced from different locations and then the latencies are recorded by ping commands, and the gathered information about latencies is converted into distance. The intersection of the regions provides a new possible region with many locations or a single location where the target might be located. This method of geo-location is termed Multilateration.

Figure 2.2 represents an example of a multilateration method. The circles around the monitors represent the distance to the target IP obtained through pings. A ping measurement is a way to measure round-trip times using physical distance (geographically) in meters and round-trip time (round trip time) in seconds. Using this relationship, we can obtain another rule of thumb: for every millisecond of RTT, 300 kilometers of distance are discovered (in the case of fiber), but in most cases, 100 kilometers per minute is calculated [20].

2.3.3 Constrained Based geo-location (CBG)

Constraint-Based Geo-location (CBG) [21], is introduced in 2006, as another method for improving the latency-distance correlation. A framework for aligning the delay distance correlation is presented. A geo-location system calculates the latency between monitors to accomplish this task. Monitoring takes place at a known location, which allows an accurate estimation of delay distances. Figure 2.3 shows how the data is fitted to a "best line" as a result. CBG is generally used to compare the performance

Figure 2.2: Example of Nearest Neighbors using monitors in the UK, Italy, and Belarus. The red area represents the range of Target [20]

of different geo-location algorithms, similar to GeoPing. CBG is also used as the basis for certain geo-location methods.

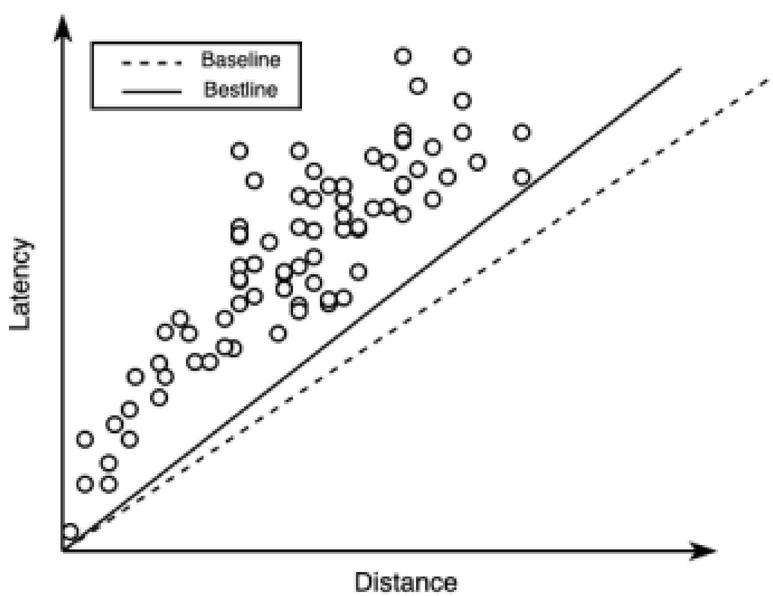


Figure 2.3: Best line and baseline relationship based on latency-distance conversion [21]

In this paper [22], the authors presented an approach to improve the accuracy of delay-distance correlation in networks with poor connectivity. This method is based on networks of sub-networks that have rich connections. Network connectivity is first measured to determine whether a network is well-connected or poorly connected. As a next step, if the network is found to be poorly connected, two methods (CBG and Geo-Get) are applied for searching richly connected networks using information from ISPs and host locations. Based on these parameters, landmarks and hosts are deployed to calculate the data such as delay, topology, and distance. From these values, the target IP is located. The results showed that the median error distance for modified CBG decreased by 50% from 629.8 km to 315.4 km. For Geo-Get, accuracy improved from 38% to 97% for poorly connected networks.

The use of the best-line relationship can be optimistic at times. According to Weinberg et al. [23], when the monitors are adjusted, network congestion (heavy traffic) can cause distance calculations to be inaccurate. This can lead to inaccurate projections, and in at worst scenario, the location can be incorrect.

2.3.4 Topology Based geo-location (TBG)

Topology-based Geo Location (TBG) [13], is considered as further work to CBG. When monitors are close to the target, CBG delay occurs based on the algorithm providing accurate results. As aforementioned, when monitors are not close to the target or there is a delay-distance conversion error, the results will be inaccurate. TBG attempts to address the issue by examining the network's topology (the Internet). It particularly geolocates in-between hops to the host (the target) while using a measuring tool such as traceroute, using the latencies of intermediate hops to further precise the locations of the relative/all hosts. All of the precise constraints are then combined to produce a larger optimization technique that may be fed into a semi-define solver (software) such as SeMuDi [23]. The first variant, TBG-Passive, employs landmarks to determine new constraints on intermediate hops (routers). TBG-undns is a second variant that also employs location hints extracted from intermediate hop host names.

Based on results compared to CBG, the TBG study concluded that it is better than CBG. TBGundns is the top-performing variation of both TBG types. However, there are some limitations to the TBG technique. To begin with, when compared to ping measurements, traceroute measurements take more time than ping. Second, it is an entirely different technique from prior basic geo techniques, therefore it is required optimization to obtain a solution. In terms of computation, it is a too expensive process. The authors in [24], proposed a scheme to overcome delays and a limited number of landmarks. Based on point of presence network topology, a new City level geo-location algorithm is presented. Through path detection and landmark detection, the network nodes associated with the target city are selected. The next phase involves determining and merging those routes from path information that are using the common anonymous route structure. At the end of the last phase, the PoP network topology is extracted from strong routing nodes and recorded in a PoP database. It is used to locate the nodes within a city. Despite the small number of landmarks and low delay precision, a city-level geo¬location is improved. Using this city-level geo-location algorithm, the success rate increased from 74.86% to 97.67%.

2.3.5 Shared Path geo-location

The concept of shared path geo-location is a newly defined approach toward active geo-location techniques. It works in this simple way where the traceroute is run to several landmarks, and the path with several intermediate hops is saved, as well as hop latencies and overall rtt, are recorded. When a target is to be geo-located, a traceroute to the target is run and then examined to check the same hops as any landmark's hops. The latencies between the landmark, target, and last shared hop are used to determine the exact location of the target.

Towards Street-Level Client-Independent Geo-Location [25], the authors used the method known as Street-Level Geo-location (SLG) in a project, together with a web mining technique for producing landmarks as explained in the Structon framework. In the initial phase, the CBG method is employed to narrow down the target's possible location. In the next phase, online mapping services are used to locate on-premises sites at organizations near the target, using queries like "company," "university," and "government office," and restricting results to certain zip codes. These sites' hosting servers also then functioned as landmarks. As shown in Figure 2.4, the estimated position of the target is chosen as the landmark with the lowest estimated latency (calculated by adding the delays from the nearest common routers).

SLG is published in 2011 and first came into popularity as cloud hosting gained attraction. As a result, many of the sites from which location data is scraped are likely hosted by cloud providers. Thus, landmark verification techniques needed to be employed to determine whether the site is hosted locally or in a data center. The proposed method uses both the hostname and IP address of a landmark site to access it. If a site is being accessed via both its IP and hostname, it is likely hosted locally, making its location information more accurate. If a site is accessible via both its IP and hostname, it is probably being hosted through a CDN or sharing hosting platform.

However, landmark verification is unlikely to be effective in today's internet technology. Due to SSL certificates being issued for domain names and not IP addresses, only websites that adhere to proper security procedures and serve over HTTPS are accessible via their IP address. Thus, SLG published its study in 2011. Google reports only 44% of Chrome users' traffic which is served over HTTPS in 2015, but that figure has since risen to 96%. Consequently, in today's internet, it is more difficult to find HTTPS-only web servers.

Besides mining the web for landmarks, SLG is used the query logs from a mapping service to derive IP address-to-place mappings. For example, if a large number of queries came from one IP address asking for directions from Fulham to other places, then the IP address could be regarded as being in Fulham, London. Neither the SLG study nor the analysis looks at landmarks in other countries besides. The U.S. Therefore, the number of landmarks that would be used is not clear.

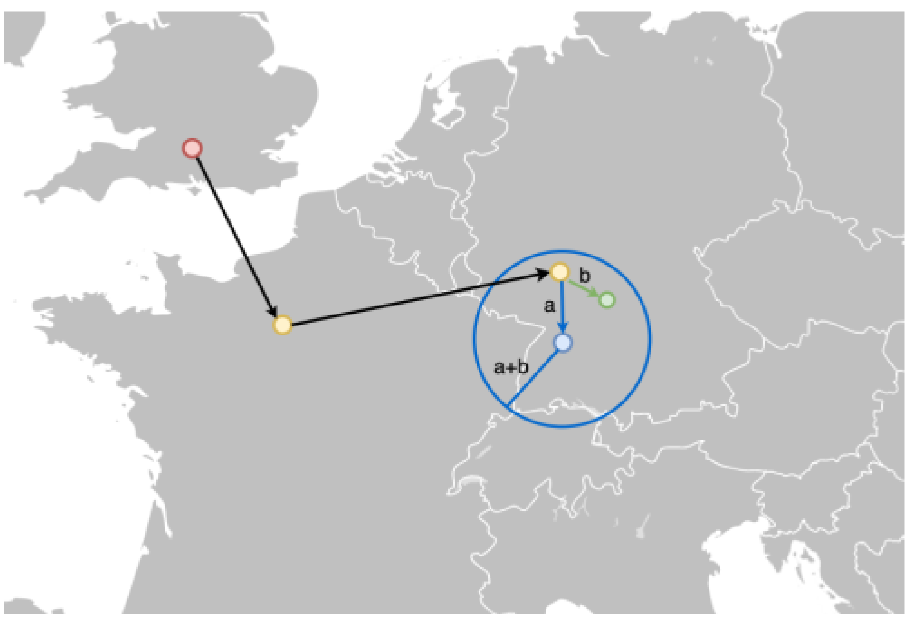


Figure 2.4: Shared Path Geo-Location Approach to Find the Target's Location [4]

The error resulting from SLG is reduced by 10% by using the approach described in [4]. However, this methodology suffered from the same major issue as SLG: In this method, local IPs and domains are separated from cloud-hosted websites. However, it does not work for HTTPS-only websites. In comparison to the rest of the globe, this study has mainly concentrated on China because the sites hosted there are mostly HTTP. Statistically, China is the lowest rate of HTTPS adoption in the world, according to Google and Mozilla, excluding countries with poor internet connections or/ people [26]. In conclusion, the CRG approach is adequate for landmark verification in China state but not working well in the global state.

An issue related to the delay-based measurement for city-level geo-location is discussed in [27], because of weakly connected networks and network topology. Topology for landmarks within the same city is found first. The traceroute method is used to calculate the routing paths for landmarks located in the same city and the target IP address from multiple probing points. Thus, the final topology is determined. In the next step, unique identification routers are determined based on landmark routing path information. If the routing path information of the Target IP matched with identification routers, then the Target IP at city-level geo-location is found. CLG's correct rate increased from 50% to 92% as a result. A method for dealing with street-level geo-location due to unknown routers is also presented in this paper. Using the above results, the local delay is calculated between Target IP and landmarks. In the end, the location of landmarks with the most similar delay to the target IP is used for Street-level geo-location to provide more accurate results. Compared to traditional SLG, the median error for 505 targets measured less as 4.3 km rather than 5.8 km.

Until now, various studies have shown improvements in existing systems, as well as certain limitations; in general, the methodologies of both passive and active geo-locations are characterized as follows [8]. The studies focused on analyzing the available IP to geo-location techniques in terms of maximum accuracy. The paper also described the causes of IP geolocation errors. Authors in [8], described that most of the network measurements are affected by:

1. Communication Technology
2. The amount of data traveling over the network may cause packets to be delayed.
3. The replay time of the destination depends upon software and hardware configuration..
4. Nodes provide unnecessary routing to data packets for traveling between host and destination.

Using the same approach that is presented in [4], the latest study is much more accurate because landmark mining had been eliminated. GeoCAM [7], utilized ad¬vanced landmark mining in conjunction with a shared-path geo-location approach. Instead of focusing on landmarks, they analyzed webcams and CCTV cameras which are used to monitor physical places which have their unique landmarks. Such landmarks are a rich source of high-quality landmarks with an exact and promising location that can be used for IP-based geolocation. GeoCAM monitors websites with webcams or CCTV cameras regularly. IP addresses are retrieved based on NLP (Natural Language Processing) techniques using webcam latitude and longitude information. GeoCAM generates landmarks on a global scale using latency. To estimate the pinpoint, topology constraints and webcam landmarks are used to estimate the geo-location of a target.

In GeoCAM, the target host is identified by first identifying the region which is located based on delay distance. Based on these distances, the fine region is identified. In that fine region, landmarks are selected by removing those that are not relevant to the target. After that, based on the landmarks selection, Multilateration is performed to locate the target IP. Active geo-location algorithms can be used to locate the target (CBG [21], Octant [39], and Spotter [40]). The GeoCAM geo-location algorithm combines constraints based on a network topology with a Spotter to achieve geo-location. GeoCAM finds the location of a target by:

Table 2.1: Summary on Related Work

Ref	Main concerns to address	Associated work (used scheme)	Evaluation Metrics	Improvement
[3]	Accuracy of client-independent Geo-location	Error free ground truth data sets along GPS precise locations	Accuracy	IP data set accuracy improved
[4]	To improve user physical location accuracy with few landmarks available	A unique IP Geo-location method relying on routers as secondary features	Accuracy	Improved user physical location accuracy and decreased maximum Geo-location errors
[8]	To improve accuracy of Geo-location using IP address	RIPE Atlas Platform	Accuracy	More feasible IP Geo-location infrastructure in term of precision and scalability
[24]	Due to limited number of landmarks and latency precision of algorithms	an approach for SLG depending upon PoP network topology is proposed	Latency	success full data transmission improved upto 97.67 percent
[28]	Verification of missing and inaccurate Geo-location databases	a concept of fusion based on correlation and similarity in delay	Latency	Accuracy 8.9 percent improved
[29]	To reduce PoP having only non-backbone nodes	sub netting task to PoP partitioned areas	Accuracy	mproved success full data rate of Geo-locating end user(EU)
[30]	Inaccurate and incomplete databases	Extracting location through reverse DNS approach	Accuracy	This approach speeds up more than 150XP
[31]	To extract the router names from host names stored by network DNS zones	To propose a system that automatically learns router names from host names stored by network DNS zones	Consistency	9 times more accurate IPv6 routers and 105 percent improvements in IPv4 found
[32]	To reduce inconsistency of Geo-location databases by multiple methods	Narrative method to manipulate Geo-location data sets	Consistency	99 percent precise results for province and 81.65 percent precise results for city achieved
[33]	to improve IP Geo-location based on neighbour sequences	Relying on neighbour orders an IP Geo-location method	Accuracy	Mean error obtained between 20 km and 30 km Geo-location of IP addresses found
[34]	To understand how to extract Autonomous System Numbers (ASNs) from host names associated with router interfaces using regular expressions	Using Topology constraints from trace route paths	Accuracy	The error rate from 1/7.9 to 1/34.5 reduced and from 87.4 percent to 97.1 percent agreement increased
[35]	To overcome issue of inconsistent format of city-level and street-level landmarks	A multi-source landmark algorithm named as Lusion	Consistency	Accuracy improved up to 8 percent compared with original data sources
[36]	To measure accurate relative delay in a city	SLG method relying on multilayered routers	Accuracy	Error reduced from 31.36 percent to 13.96 percent
[37]	To exploit user physical information hidden in HTTP headers and cookie sent	Whois Data driven approach	Accuracy	Greatest accuracy at continent level and least for coordinate accuracy
[38]	To improve relative delay and physical distance for hosts sharing closest common routers	A narrative SLG approach	Accuracy	Aimed accurate physical Geo-location in overall world improved

1. Measure the RTT to landmarks and the target from the probe point by traceroute.
2. Determine the distance between the landmarks and the target using the shared hops.
3. Finally, estimate the target with maximum likelihood.

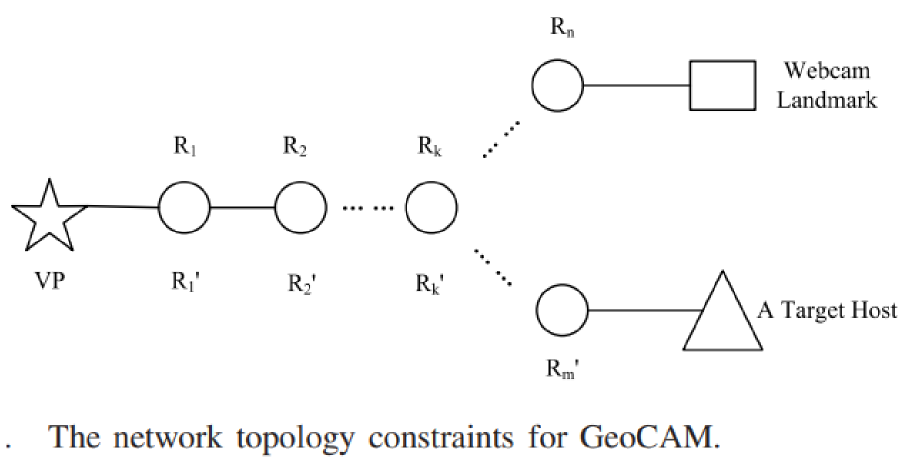


Figure 2.5: Network Topology Constraints for GeoCAM [4]

When using active geo-location algorithms, accuracy increases by 60% higher by using webcam landmarks instead of open-source landmarks. The algorithm first searches the webcam in detail for the same position, for each landmark and target path sharing the same hops during the traceroute. Then the router (hop) is found that is closest to both landmarks and the target denoted as Rk = Rk'. Adding T (Rk, L) and T (Rk, T) showed the latency between the landmark (webcam) and the target, where T is the latency, Rk is the same router (hop) closest to both landmarks, L is the landmark, and T is the target. Existing results extracted from [4], [7], and [25], highlighted the importance of a high number of landmarks for better IP to geolocation.

Several studies on IP to geo-location mapping are summarized here. Except for GeoCAM, which uses landmarks as global data and has a better physical location, its accuracy can be increased by identifying the last router between Landmarks and Target IP. The accuracy claims for IP to geo-location are improving and true IP location mapping using IP camera-based landmarks and reached 94.20 accuracy [7]. However, the accuracy, reliability, and latency of IP to geo-location mapping techniques can be further improved.

Chapter 3

3.1 Proposed Methodology

This chapter describes multiple measurement frameworks for IP to geo-location mapping aimed at higher accuracy.

1. When an IP request is received, the first step is to check the database (16K+ CCTV LMs).

2. If geo-location information is presented in the database and updated, this data is passed to the digital end, if not available, then Autonomous System Number (ASN) is used to obtain the ISP, region, and country of that IP.

3. By using the ASN information, landmarks are filtered out so that they can be used to determine the region-based landmarks. The region-based landmarks step may also be skipped as filtration algorithms are used to get filtered landmarks closer to the target(Effective in theory and practice).

4. After having all the filtered landmarks, the next step is to use active measurements (traceroute + Ping) to geo-locate the IP address.

   (b) (b) In addition, a shortlisting algorithm is applied to get even more landmarks that are closer to the target, as shortlisted landmarks will be those landmarks with the most shared hops.

   (c) (c) Hence, we determine a delay-distance relation between short-listed landmarks and the last routers, and multilateration is performed to pinpoint the target.

5. Finally, the location of the IP address is determined and passed along to a GUI (Graphical User Interface).

3.2 Last Router Geo-location (LRG) Framework

Figure 3.1 shows how an IP address is geo-located by using the Last Router Geo-location (LRG) framework. A framework for geo-locating IP addresses is described in the section and includes a traceroute using the LRG approach and the details of active measurements using measurement tools. In section 3.1. The framework's overall flow is discussed; however, the LRG part needs a bit more explanation in more depth. The algorithm works as follows:

1. Measuring the paths for target IP, then finding landmarks that are on the same hop.

2. They are further shortlisted based on landmarks and matching hops. The aim is to match hops to get landmarks that are close to each other while targeting.

3. Then, latencies between the last routers and landmarks are determined through the traceroute method and then these values are converted into distances.

4. After determining the distance between landmarks and the last router, the information can be used to find the location of the target by finding the intersection of those circles. Multilateration and CBG methods can be used to find feasible regions of Target.

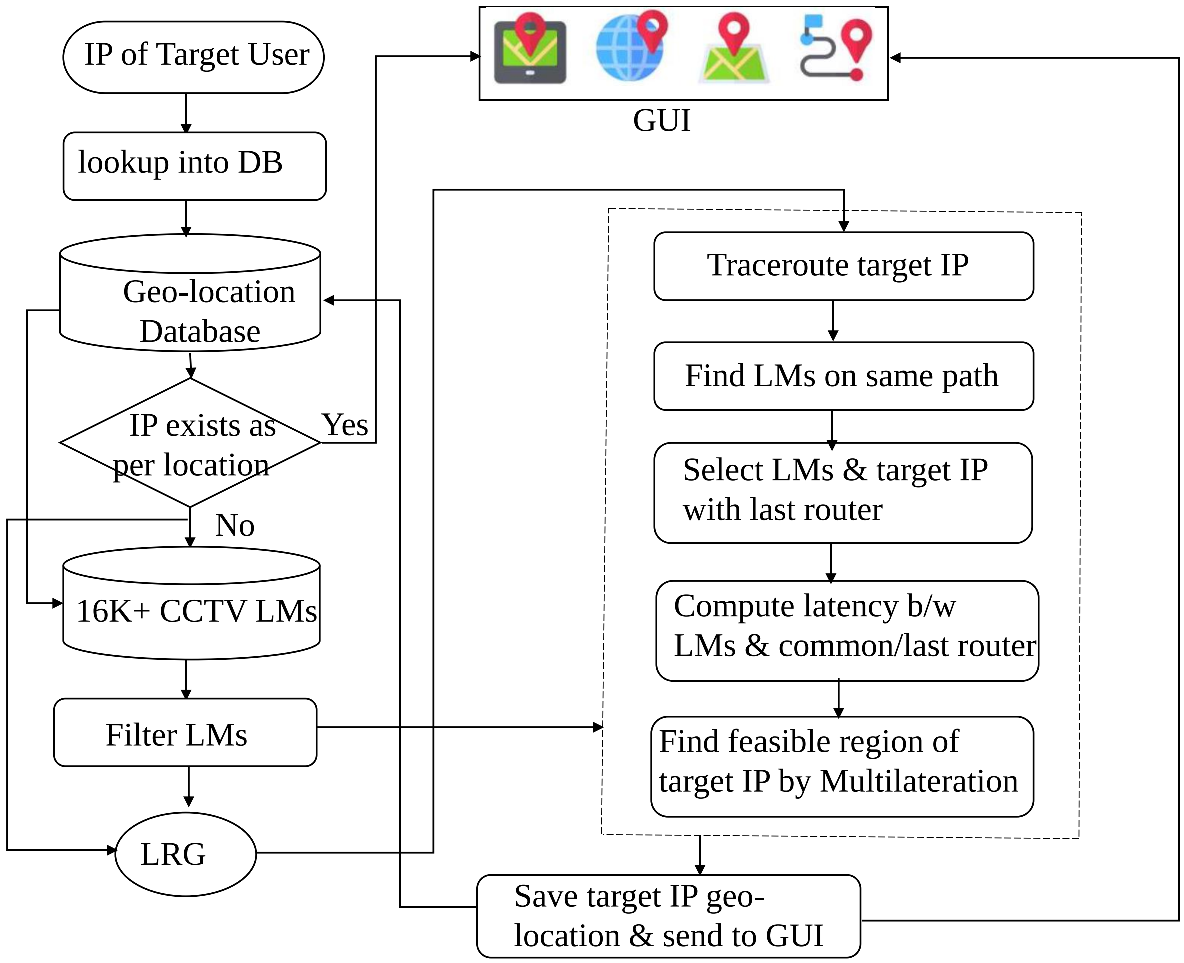


Figure 3.1: shows the Last Router Geo-location (LRG) Framework.

3.2.1 Trace route using Last Router Geo-location (LRG) approach

The last router's Geo-location (LRG) mechanism is shown in Figure 3.2. Using the ISB-based monitor, run a traceroute command on three landmarks (L1, L2, and L3) by using the last hops (h1, h2, and h3). The location of the target can be determined by finding the delay-distance relation from the landmarks to their last routers respectively. Equation 3.1 is used to find latencies between the last routers and landmarks.

$$H(R_l, L_i) = H(P, L_i) - H(P, R_l) \tag{3.1}$$

Where H represents latency, L denotes Landmarks, P is the probe point from where the target is being located and Rl is the last router for each landmark. Latency values are converted to distances to make three circles (C1, C2, and C3) According to the mathematical model, delay and accuracy are inversely proportional to each other. If the delay is minimum, then accuracy will be maximum and vice versa. To convert latencies into distances, Equation 3.2 is used.

$$d(x, y) = RTT/2 * 2/3 * c \tag{3.2}$$

Where RTT/2 represents the one-way latency between x and y, and c represents the speed of light in a vacuum. Furthermore, a precise region of the target IP is obtained.Figure 3.2 shows the traceroute using the last router geo-location (LRG) approach.

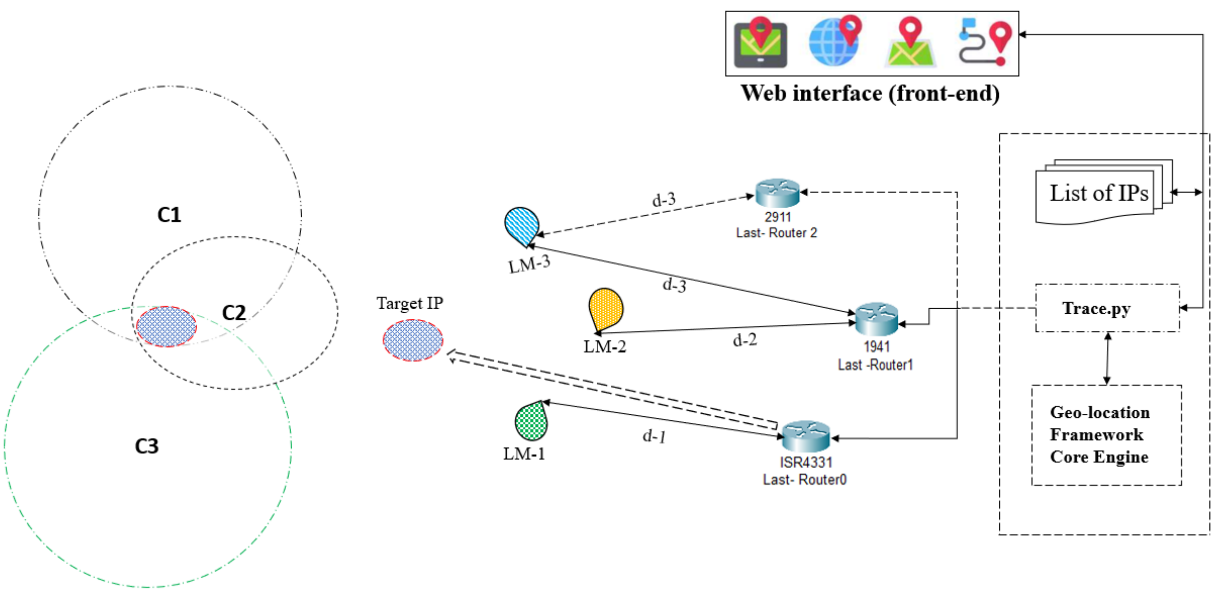


Figure 3.2: Trace route using Last Router geo-location (LRG) approach

3.3 Operations of Proposed Multi-Measurement Framework

The framework presented above for geo-location consists of three (3) main modules. It can be expanded in the future. There is a need for a traceroute measurements module that processes measurements, a filtering module, and a shortlisting algorithm, as well as a calculation module that performs all the calculations necessary for geo-locating a specific region. It is necessary to follow the flow of the system to understand the importance of all modules. Taking an IP location for the experiment is

IP: 2.44.120.242, **Latitude**: 16.250190, **Longitude**: 39.309990, **Location**: Cosenza, Italy

3.3.1 Active Measurements

After obtaining an IP address (2.44.120.242), the first step is to run a traceroute to get the route path for that target (basically, all intermediate hops). The next step is to find the same hops from the traceroute records of the landmarks fetched in the database. The match hop method works by passing hops one by one to it and helps to identify landmarks that are located earlier in the traceroute record. When any matched hop in the database is found, it provides its landmark ID. Likewise, the next hop in the target's traceroute is returned. In the next step, the match hop examines the records and returns a landmark for all matched hops, and the traceroute record is completed for the target. The number of hops depends upon that target IP for example if we want to check any target IP in Pakistan then it will have a maximum of 4 to 5 hops due to the limited availability of webcam landmarks in Pakistan. Optimization is carried out by picking only the half of traceroute records for the target in this module. Initial trace route records relate to local ISPs and gateways, which are typically located far from their targets and are unnecessary. So when an IP address is provided as a target IP address during the traceroute, half of the hops are taken for further proceedings. Figure 3.3 displays the traceroute record for an IP (2.44.120.242):

```
Tracing route to net-2-44-120-242.cust.vodafonedsl.it [2.44.120.242]
over a maximum of 30 hops:

  1    <1 ms    <1 ms    <1 ms  172.16.208.1
  2     1 ms     1 ms     1 ms  111.68.99.17.bahria.edu.pk [111.68.99.17]
  3     2 ms     2 ms     2 ms  172.31.252.53
  4     5 ms     1 ms    <1 ms  172.31.240.8
  5     3 ms     3 ms     2 ms  tw23-static237.tw1.com [117.20.23.237]
  6    20 ms    20 ms    21 ms  tw255-static67.tw1.com [110.93.255.67]
  7    21 ms    21 ms    21 ms  110.93.252.172
  8    21 ms    21 ms    22 ms  110.93.253.22
  9     *        *        *     Request timed out.
 10   134 ms   133 ms   134 ms  ae1.10.edge1.Milan1.level3.net [4.69.162.221]
 11   132 ms   132 ms   133 ms  185.210.48.24
```

Figure 3.3: Trace route Records for Target IP using Command Prompt

The algorithm will only select hops after 07 to 11 because of the optimized approach. Thus, only promising hosts remain, from which can obtain landmarks that have the same hops. As an example, consider IP 2.44.120.242 is using a known location (Florence, Italy) as a target. In this case, it will get landmarks with matched hops as follows.

Fetched Landmarks: 32

[35863416, 1564887396, 48656328, 1564948898, 1594629075, 3168278730, 3001642451, 36311066, 3160362234, 48316904, 2684328072, 2264903466, 3113784540, 36363946, 48418482, 35856390, 48623620, 48296575, 48491054, 48407936, 48363525, 90058757, 48534613, 48583449, 3113448603, 48279690, 1569736861, 36468978, 2433655894, 1564946124, 1364993109, 1406355320]

The next step is to analyze the landmarks according to their number of matching hops. From this, we can find all the matched landmarks initially.

Landmarks with matched hops: 32

[1564887396: 4, 1564948898: 4, 3168278730: 4, 36311066: 4, 36363946: 4, 35856390: 4, 90058757: 4, 1569736861: 4, 36468978: 4, 1564946124: 4, 35863416: 3, 48656328: 3, 1594629075: 3, 3001642451: 3, 3160362234: 3, 48316904: 3, 2684328072: 3, 2264903466: 3, 3113784540: 3, 48418482: 3, 48623620: 3, 48296575: 3, 48491054: 3, 48407936: 3, 48363525: 3, 48534613: 3, 48583449: 3, 3113448603: 3, 48279690: 3, 2433655894: 3, 1364993109: 3, 1406355320: 3]

By using the filter landmarks method, a dictionary is returned, using landmark as the key and matched hop numbers as the value. After fetching all landmarks with matched hops, only those landmarks are picked that have the most significant hops, among all only three landmarks are picked. Hence, it will only show the landmarks closest to the target since they are using the same route to reach the target (partially).

Filtered Landmarks
[1564887396, 1564948898, 3168278730]
The shortlisting algorithm is introduced following the collection of three closed (technically) landmarks according to the most recent matching hops with the target. The closer the landmark and target are, the more end hops they have in common and the topologically closer they are.

3.3.2 Shortlisting Algorithm for Landmarks filteration

A second function of the framework involves short-listing landmarks near the target. Concerning Section 3.2 for more information, we will use a developed shortlisting algorithm to filter and shortlist landmarks. The algorithm checks half of the targets from the last with the landmark hops (half). Based on matched hops, the landmark is given a score based on its location, and after matching all hops, the landmark is given a total score. Landmarks are selected based on Short-listing algorithm and landmarks-score are given near to Target IP based on that algorithm. Table 3.1 shows the landmark-hops and target-hops tables.

Table 3.1: Table for Landmarks-hops and Target-hops

Target (Hops)	Landmarks (Hops)
2	2
3	5
6	6
5	8
4	4
9	0
0	7

The record is derived from running traceroute measurements in Table 3.1. Hops' actual IP addresses are replaced by numbers to make it easier to understand. In step one, 0 is picked since it is the last hop of the target, and then the matching algorithm is looped over landmark hops. The last landmark hops in condition 0 and will not match the Target hop, so the pointer points to the second last landmark hop, which will match the target hop. The final score is calculated this way: target hop pointer - landmark hop point score. While the target hop pointer is based on the hop length of the total hops and the landmark hop point counter is the loop's iterative count. So, a landmark hop match would end with the landmark score of $7-1 = 6$.

Similar to the loop, the landmark hops will continue until they reach the middle. After that, the algorithm will select the next target hop, which is 9, and continue the matching process. In this way, we will end up with a list of landmarks and their scores. The algorithm picks the top 3 landmarks based on that score.

Short-Listed Landmarks

[1564887396: 18, 3168278730: 12, 1564948898: 10]

Algorithm 1 Shortlisting Algorithm

```
target_ip_details = [[ip], [[hops count], [time], [host]]]
landmarks = filter_ landmarks(target_ hop_ details, fetched_ landmarks, 4)
DEFINE FUNCTION shortlist_landmarks(target_ip_details, landmarks) :
SET score to 0
SET d_tp to tp to len(target_ip_details[1][1]) − 1
SET max_tp to tp/2
SET shortlisted_landmark_score to 0
FOR landmark IN landmarks :
    SET hop_details to extract_trace route(landmark)
    SET d_lp to lp to len(hop_details) − 1
    SET max_lp to lp/2
    WHILE 1 :
        SET t_host to target_ip_details [1][2][tp]
if t_host ! = '∗' : then
    SET l_host to hop_details [lp][2]
    if lp ≥ max_lp : then
        if convert_ip(t_host) then
            EQUALS l_host :
            score + = (tp − (d_lp − lp))
            tp − = 1
            lp − = 1
        else:
            lp − = 1
            :
            if tp ≤ max_tp : 3 then
                SET tp to d_tp
                SET shortlisted_landmark_score [landmark]
                SET score to 0
                break
                tp − = 1
                SET lp to d_lp
            else:
                tp − = 1
                SET shortlisted_landmark_score to dict(sorted(shortlisted_landmark_score.items()
                , key = lambda item : item[1], reverse = True))
                Return shortlisted_landmark_score
```

3.3.3 Working of Short-listing algorithm

1. In the above algorithm first of all target-IP-details [(IP), (hops count), (time), (host)] are found through the traceroute method.

2. Then top 4 landmarks are filtered based on a maximum number of matched hops in ascending order.

3. Then landmarks are shortlisted by using the above-designed algorithm.

4. The algorithm checks half of the targets from the last by setting target pointer (t-p) to (t-p)/2 and (l-p) to (l-p)/2 with the landmark hops (half).

5. Based on matched hops, the landmark is given a score based on its location, and after matching all hops, the landmark is given a total score.

6. After the implementation of different conditions in terms of decrement, the short-listed landmarks are returned as a dictionary where the landmark is key and the hop score is its value and in this way, better landmarks are shortlisted.

3.3.4 Multilateration

Once the landmarks have been shortlisted, the last operation is to determine the distance between the last routers and the landmarks. To determine the physical distances between the last routers and landmarks, we will use the latency approach first derived from Equation 3.1. We have short-listed landmarks when we run the short-listing algorithm. To convert latencies into distances, d (x, y) = RTT/2 * 2/3 * c is used, where RTT/2 represents the one-way latency between x and y, and c represents the speed of light in a vacuum. In fiber optics, the upper limit of light speed can be used instead of the delay-distance relation formula. The speed of light is 300km per second. In fiber optics, it's approximately 200 kilometers in 1 ms. If 1 ms is 300 kilometers, 2 ms is 3 * 300, and so on.

Trace route Details for delays between last router and landmarks:

: ['93.70.73.99': 144.703, '188.216.24.202': 134.7896, '93.71.57.162': 127.64000000000001]

details (Km) converted from delay details:

[('93.70.73.99', 43410.9): (45.4581, 7.87192), ('188.216.24.202', 40436.8): (45.81, 9.08744), ('93.71.57.162', 38292.0): (45.6678, 8.17961)]

Results indicated that straight line distance is far more accurate than distance derived from delay distance because of ping measurement error. An accuracy check is performed at the city level. The results seem promising. A selection has been made based on the shortlisting algorithm. This involves landmarks within a city with a maximum distance of 103 kilometers as shown in Figure 3.4.

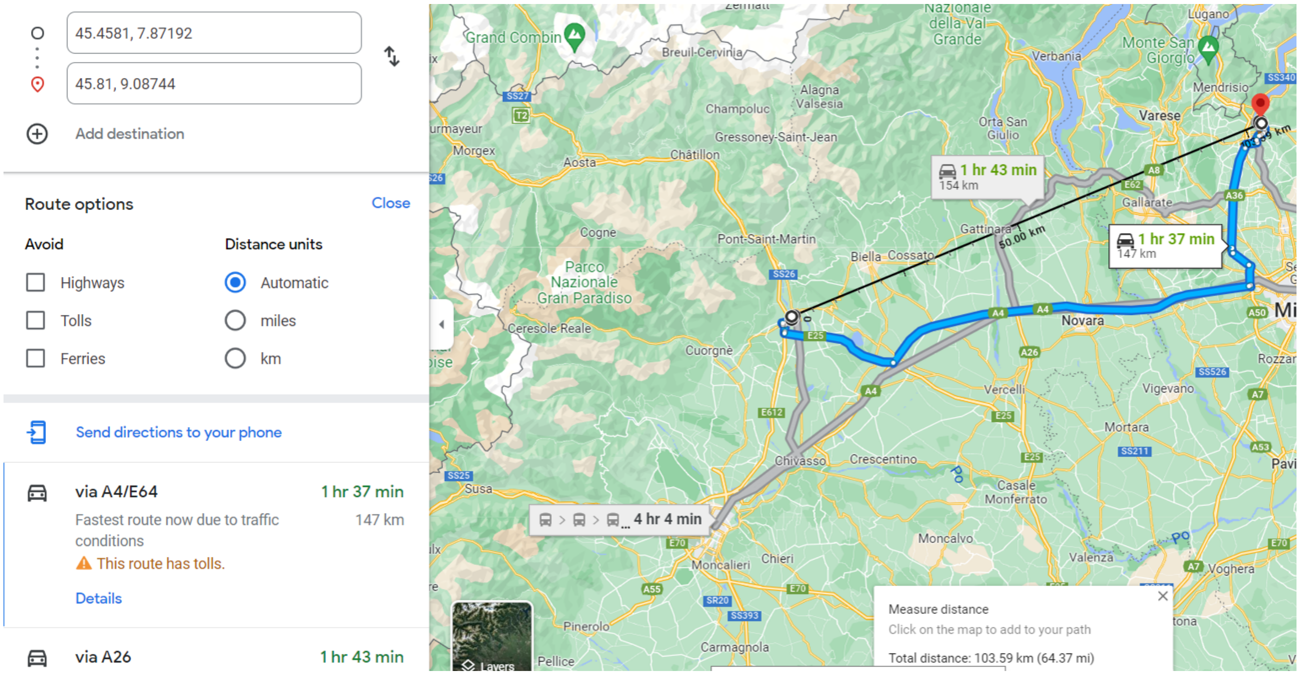


Figure 3.4: Distance between landmark 1 and landmark 2

City Level details:

[‘2.44.120.242’: ‘Unknown’, ’93.70.73.99’: ‘Ivrea’, ‘188.216.24.202’: ‘Como parking view’, ‘3.71.57.162’: ‘Pratrivero s.p.a’]

The first IP is the target, and “Unknown” is purposefully assigned in order to check city-level accuracy for shortlisted landmarks. Coordinates of the landmarks and targets are all stored, but for testing purposes, only the landmarks are used on the map, and the distance between landmarks and targets is manually calculated. This indicates that the landmark filtration is accurate. Here the distance between Landmark1 and Target IP is 968 KM shows in Figure 3.5.

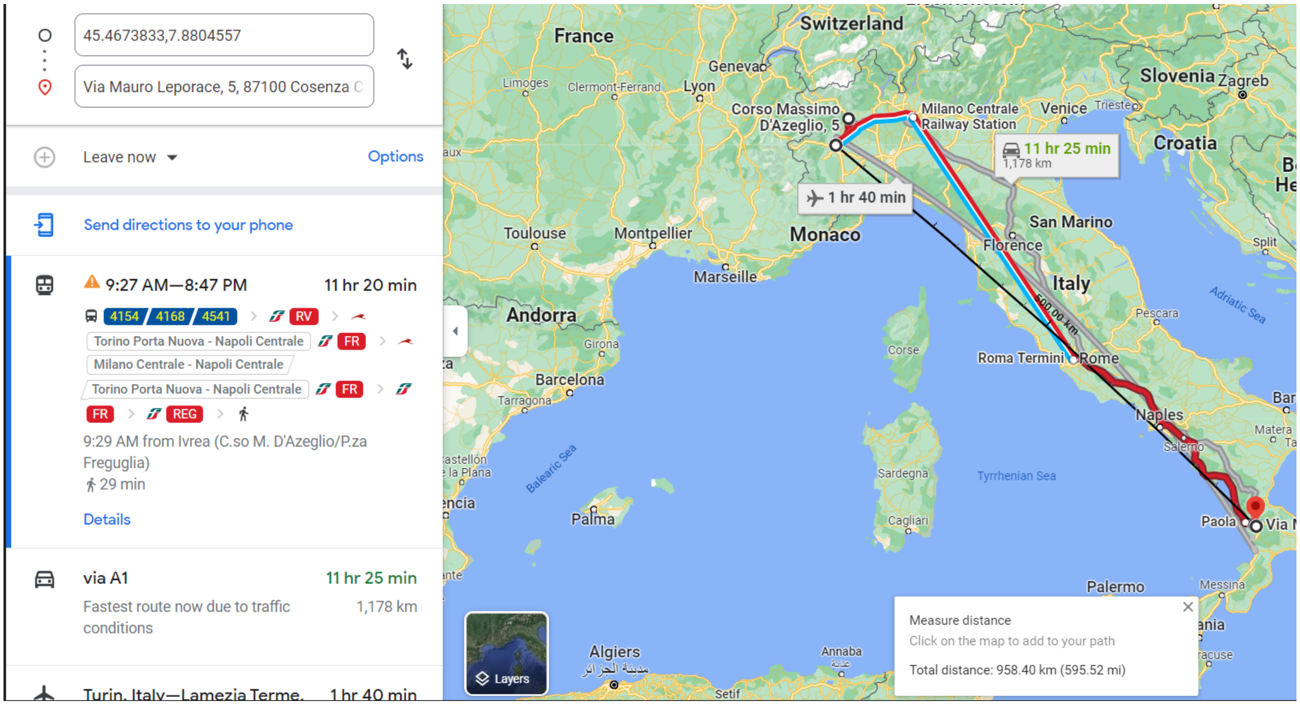


Figure 3.5: Distance between landmark 1 and Target IP

Chapter 4

Implementation and Results Analysis

In this chapter, implementation and results analysis are presented in detail.

4.1 Implementation of Proposed Methodology

Figure 4.1 shows the geo-location system architecture. The back-end design (core engine) details each module in the proposed system involved in the geo-location process. It contains all the applications (actual code) that make up active measurements, filtration, and multilateration. While the front-end interface provides a brief explanation through which the system can interact to Geo-locate an IP address.

4.1.1 Web Interface (Front End) – GUI

To implement the geo-location system, a web-based interface is developed so that end users can access HCI panels. It includes user input through which geo-location can be done by providing an IP address or a list of IP addresses. Using this front-end, the solution meets HCI requirements.

4.1.2 Geo-location Framework (Back End) – Core Engine

This is a python-based script that contains all the necessary tools and code, to geolocate an IP address and NS-2 can be used in terms of simulation. The proposed work is purely real network simulation based whereas Pycharm uses a simulation tool for IP to geolocation. Geo-locating an IP address isn't just a simple task requiring a single piece of code; instead, it requires a complex framework with OOP modules that manage each important task and measurement for the overall framework. Figure 4.1 illustrates the working details of the geo-location architecture.

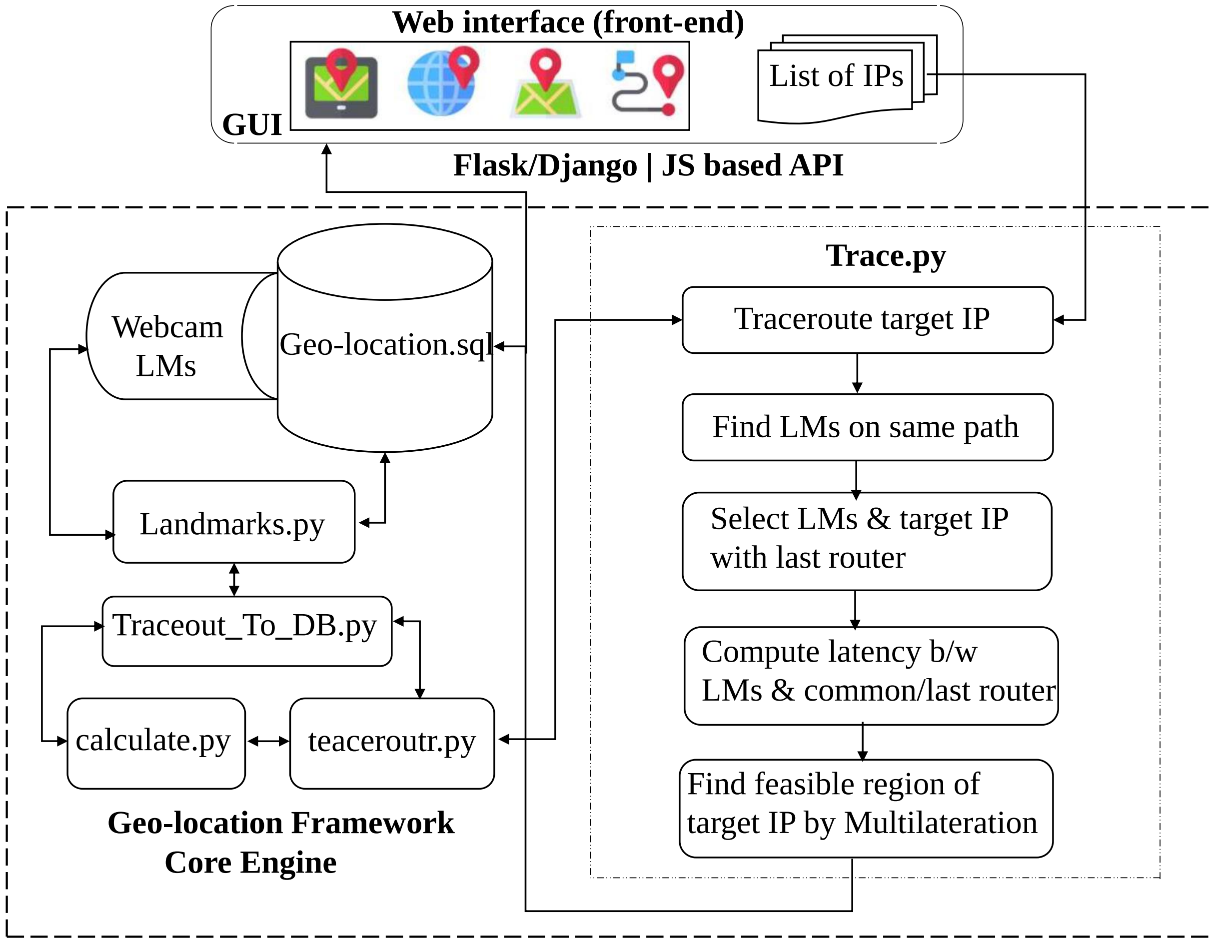


Figure 4.1: Architecture for geo-location system

4.1.3 Measurement Tools

The main purpose of this module is active measurements. When an IP address is provided for active geo-location, it checks the traceroute measurements, so the trace route.py module contains those measurements, in addition, to all the necessary code to handle such active measurement tools. These tools include traceroute and ping. This module is also responsible for tracing routes for all available landmarks (8k+) and storing trace records in the database. It is accomplished by using Landmarks.py and traceroute to DB.py collectively as well as trace route.py. Global Positioning System (GPS) cannot function without the internet, but satellites can still detect the GPS radio when there is no data connection. GPS does not use data; it simply receives satellite signals that are independent of cell service. In reality, the device uses a GPS, requiring help from the cell carrier, and work is not based on GPS locations due to the presence of all traceroute records in the geolocation database.

4.2 Selection of Algorithm

After measuring the traceroute and extracting hops for any given target, the next step is to select landmarks with matching hops in the database (the traceroute record is already stored in the database, and landmarks are fetched by measuring the module earlier using trace route To DB.py).

4.2.1 Landmarks Filteration

Furthermore, landmark selection can be performed without considering the uniqueness and diversity of the results, which may include duplicate landmarks. In this case, filtration is necessary. It involves removing all duplicate landmarks and placing all those landmarks in ascending order according to the matched hops.

4.3 Shortlisting Algorithm

This algorithm is fully described in section 3.3.2, where the shortlisting algorithm is my custom-derived algorithm that helps in selecting landmarks close to the target from the filtered list. Due to the unique nature of this algorithm, it examines the last hops for each filtered landmark and determines which landmark is nearer to the target based on the last hops that match and their scores.

4.3.1 Mathematical Calculations to perform Multilateration

After the selection of landmarks, it is necessary to determine the physical distances between vantage points and landmarks, between landmarks and last routers, and between vantage points and routers. This calculation is based on mathematical equations. Measurement of physical distances (d1, d2, d3) from delay values between Landmark and last routers is used to find the area of a circle by using the following formulas in Equation 4.1.

$$A = 3.14 * d2/4 \tag{4.1}$$

Then the circumference of a circle is calculated to find the intersection between C1, C2, and C3 to get a feasible region for the target IP address by using Equation 4.2.

$$C1 = 3.14 * d \tag{4.2}$$

Based on these three circles, a feasible region of any IP address is found. It tells the exact location of the target IP. Figure 4.2 represents the feasible region obtained by doing Multilateration for three circles of distances between landmarks and the last router.

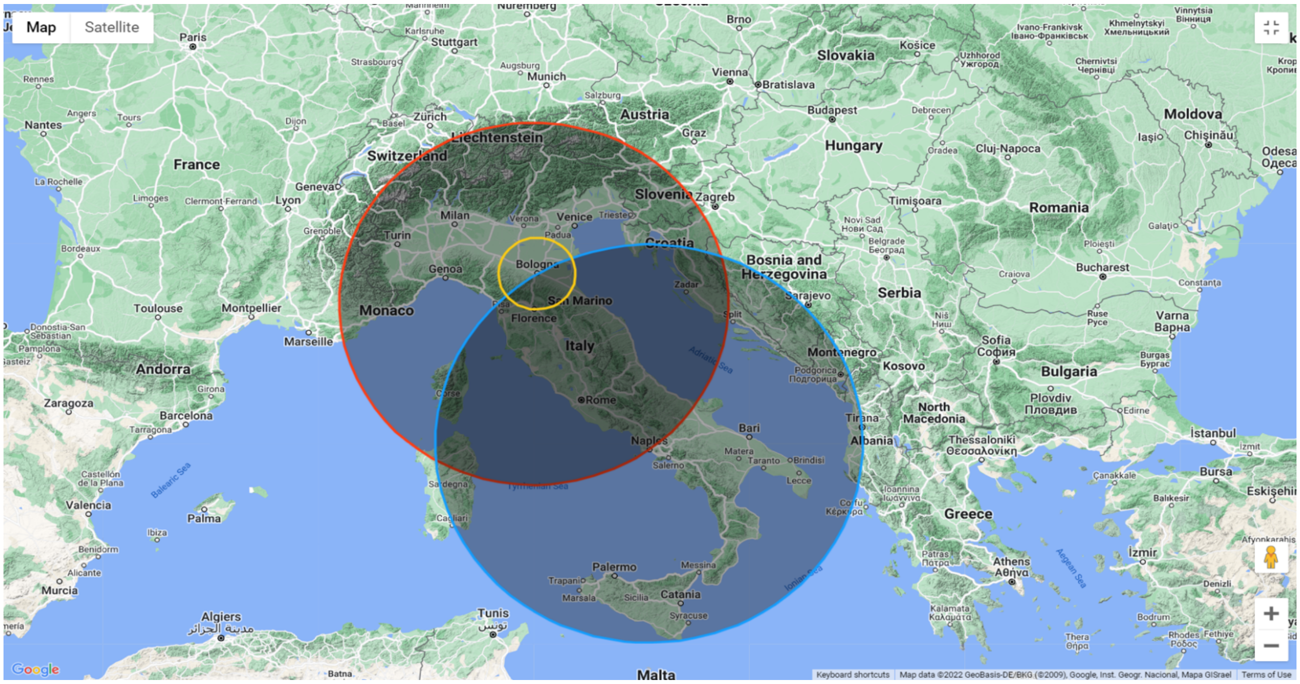


Figure 4.2: Multilateration for Target IP

4.4 Results and Analysis

This research used the IP-to-geo-location framework to analyze several randomly generated IP addresses. In this section, these results are analyzed to demonstrate that the system described in this research can more accurately detect IP geolocation. Webcam landmarks are used to geolocate an IP address using a shared-path geo-location approach with an improved landmark filtration technique that can extract landmarks near the target area much more efficiently. Webcam landmarks are also used in GeoCam [7] before this work. A webcam landmark is used to provide approximate geo-location when locating an Internet server (target).

4.4.1 CCTV Landmarks vs Open-Source Landmarks

Comparing webcams/CCTV landmarks with open source, several milestones have been achieved, such as PerfSONAR [41], PingER [42], and Planetlab [43], as well as RIPE Atlas. These comparisons are based on quantity, diversity, and coverage. Webcams providing superior image quality and accuracy can be employed to demonstrate the advantages of webcam landmarks. The proposed IP to geo¬location algorithm is applied to identify the location of landmarks. This process is known as landmark filtration. Figure 4.3 represents the coverage of CCTV landmarks worldwide.

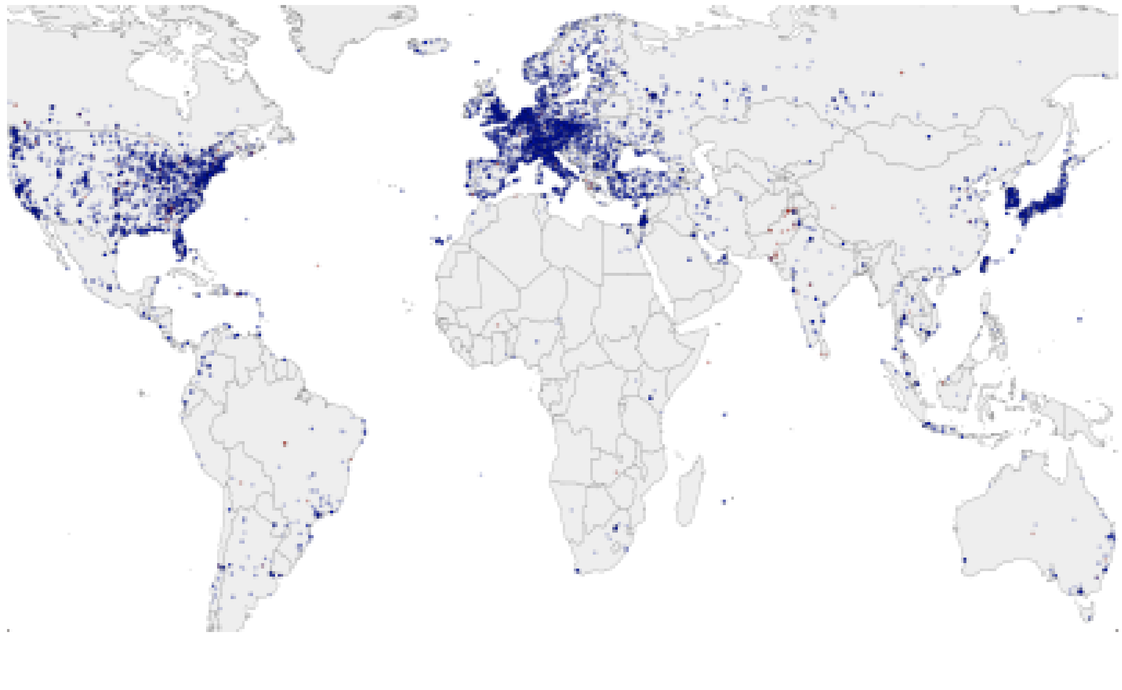


Figure 4.3: Coverage of CCTV Landmarks over the Globe [7]

1. **Quantity**

   We only checked Landmarks that are visible and accessible. For example, PerfSONAR [41] claims 2,143 nodes, however, the majority have been removed. Currently, only 642 of these nodes are available due to usage restrictions that remain in place. In addition, those landmarks originate from academic communities rather than other kinds of communities. Webcam landmarks are positioned in various types of locations with the high geographical resolution, including residential areas and other environments. In general, CCTV landmarks provide more landmarks than previous works; as shown in Figure 4.2. However, they are rendered useless when they are far from the target. Generally, geo-locating an IP more accurately can be determined by landmarks near the target. CCTV landmarks are much more numerous than open-source landmarks, as illustrated in Figure 4.3. Estimated regions of the target are produced based on landmarks that are close to the target. The accessibility of landmarks is listed in Table 4.1.

2. **Diversity**

   The landmarks cover a larger geographical area than other landmarks. Figure 4.3 shows the world map with blue dots representing CCTVs and red dots representing other platforms PerfSONAR [41], PingER [42], and Planetlab [43]. The coverage of CCTV landmarks is much greater than that of GPS-based landmarks coverage. Most CCTV cameras are located in North America and Europe. These regions are well covered by landmarks, but the rest are under-served. CCTV landmarks, on the other hand, cover a greater geographic area, such as Turkey, India, China, South America, and Russia. It describes the distribution of countries and cities for the geographical coverage of CCTV. Here are some landmarks of CCTV. There are landmarks from 170 countries and 6,448 cities. Approximately 25% of the CCTVs are European or North American. The following table lists the top 10 countries covered by CCTV landmarks, and most of them are from Europe, North America, and Asia.

Table 4.2: CCVT's Landmarks in top 10 countries

Country	**Quantity**	**Country**	**Quantity**
USA	1781	NETHERLAND	580
ITALY	1188	TURKEY	523
JAPAN	1084	CZECH	361
GERMANY	901	UK	283
FRANCE	814	SOUTH KOREA	280

4.4.2 Filtered landmarks closer to target IP

1. **Data sets:**

   The CCTV/webcam landmarks data set consisted of 100 randomly selected targets. For the landmark filtration test, we manually examined those hosts and extracted five more from the same region. The network is mobile, not static due to the diversity of landmarks worldwide.

2. **Accuracy of Proposed system with Operating System**

   For testing purposes, it performed a traceroute on different 20 IP addresses to find the last router for those IPs and delay values respectively and the same task is performed on Command Prompt for finding the last router and delay values to find the error rate for both cases. Figure 4.4 shows the comparison between the proposed system delay results and Operating System (OS) delay results.

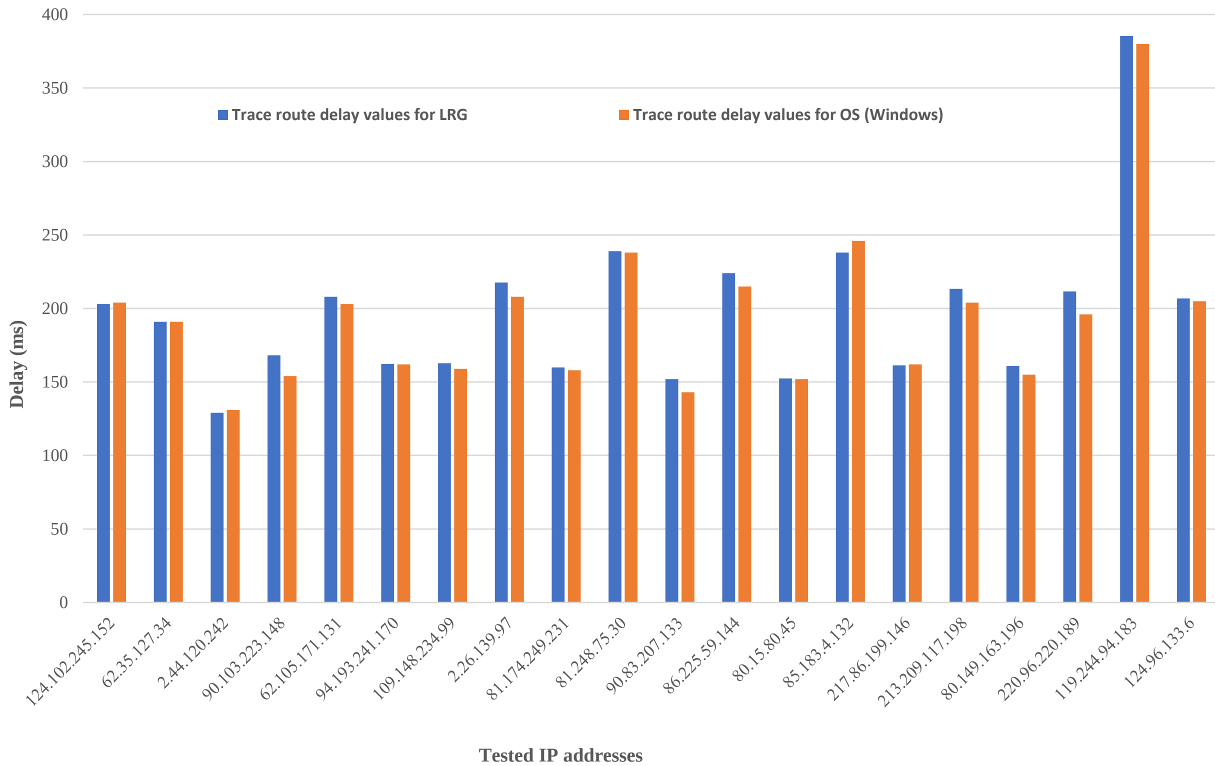


Figure 4.4: Trace route delay comparison of OS & LRG approaches

Further, it converted these delay values into distances for both cases, and the error rate is about 1% so the accuracy between these two results is nearly about 99% due to a very less error rate to prove the proposed system's efficiency in terms of accuracy. Figure 4.5 shows the comparison between the proposed system distance results and operating system distance results.

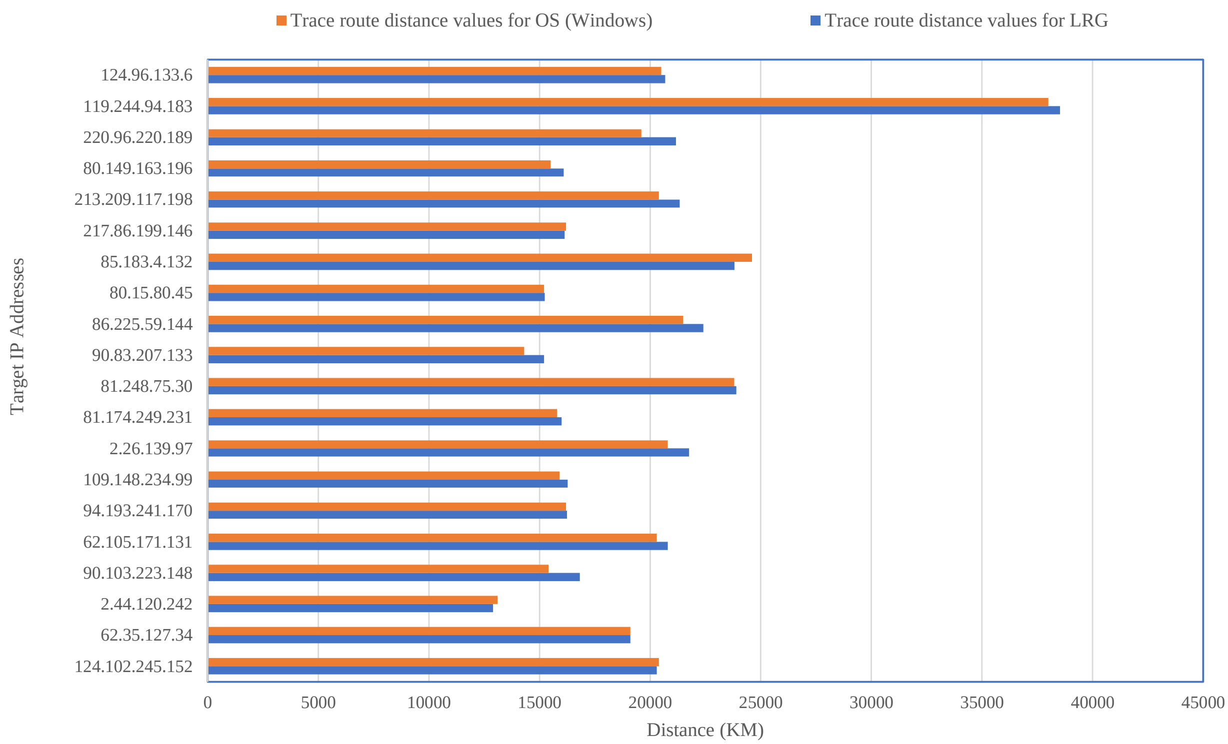


Figure 4.5: Trace route distance comparison of OS & LRG approaches

3. **Accuracy of Short-listing Algorithm**

It is easier to geolocate a target by using nearby landmarks. After inspecting fifty (50) separate target hosts, neighboring landmarks are manually inspected. Each host is assigned four nearby landmarks based on their distance from the target, and a list is created for comparison. Following this, IP to geo-location framework is used, which filtered nearby landmarks based on a short-listing method. Results from the extracted list are also used to create a second list. The accuracy of the extracted list is determined by comparing it with the manually inspected list for four landmarks. If all four landmarks for a specific IP in the list are extracted exactly along with the landmarks extracted by the proposed algorithm, then the accuracy for that specific IP is 100%, but if only three are extracted, the accuracy for that specific IP is 75%. Similarly, it evaluated fifty (50) different IP addresses (hosts); the accuracy achieved by our system was 95%. By using Equation 4.3 accuracy of the system is calculated.

$$Accuracy = 100 - Error\ Rate \tag{4.3}$$

where

$$Error\ Rate = (Actual\ landmarks - Matched\ landmarks/Actual\ landmarks) * 100 \tag{4.4}$$

The error rate is calculated by using Equation 4.4 where actual landmarks are landmarks in the inspected list, and matched landmarks are landmarks filtered by the short-listing algorithm.

4. **Inspected List**

   The simulation was performed for any individual IP address and further to check the accuracy of results, more IP addresses have also been checked. The inspected list includes five (5) host IPs and twenty (20) IP addresses that are landmarks. Approximately four landmark IPs are located nearby each host IP. Below is a list of landmarks.

   IPs: [2.44.120.242, 124.102.245.152, 217.7.205.3, 90.103.223.148, 62.105.171.131] Landmarks: [93.70.73.99, 188.216.24.202, 93.71.57.162, 192.167.33.90, 210.163.187.161, 124.96.133.6, 119.244.94.183, 220.96.220.189, 80.149.163.196, 213.209.117.198, 217.86.199.146, 85.183.4.132, 80.15.80.45, 86.225.59.144, 90.83.207.133, 81.248.75.30, 81.174.249.231, 2.26.139.97, 109.148.234.99, 94.193.241.170]

5. **Matched List**

   In [7], results are calculated for four geo-location algorithms named GeoCAM, CBG, Octant, and Spotter. All these algorithms are used webcam landmarks and open-source Landmarks. Webcam landmarks provided worldwide coverage and at least one landmark close to Target IP. All algorithms used the last shared routers using ping to calculate Round Trip Time (RTT). Then multilateration is applied to narrow down the target area and the target location is extracted based on the smallest relative delay. All algorithms have used a correlation between delay and distances for finding the estimated location of the target. The difference between the theoretical distance value and actual distance value finds out target location accuracy. For maximum accuracy, the difference is lower between the theoretical distance value and the real distance value. 20 pairs of landmarks and a target IP are selected as data sets. The relative delay value is taken on X-axis and the distance between landmarks and a target is taken on Y-axis. If the relative delay value is small, accuracy is more precise for the target location. GeoCAM using webcam landmarks achieved 60% more accuracy than using open-source landmarks. While the proposed system successfully extracted landmarks nearby the target upon running for all specified IP addresses. Unfortunately, the detection of all retrieved landmarks is not successful. 19 landmarks on the inspected list are found to be identical. According to the proposed system, with the accuracy formula, for the 20 host IPs, an accuracy rate of 95% is achieved. According to a recent study, the accuracy of the delay-distance conversion method is not more accurate for better landmarks filtration, while the performance of the proposed system in terms of overall accuracy for landmarks filtration is 95%. As a result, a comparison of these two methods for better landmarks filtration is shown in Figure 4.6. The proposed work is not just based on accuracy in terms of better results for any Target IP, reliability is also determined to check how much time results will be the same for any IP address in terms of landmarks selection or better landmarks filtration. Figure 4.6 shows the accuracy of landmarks located near the target IP.

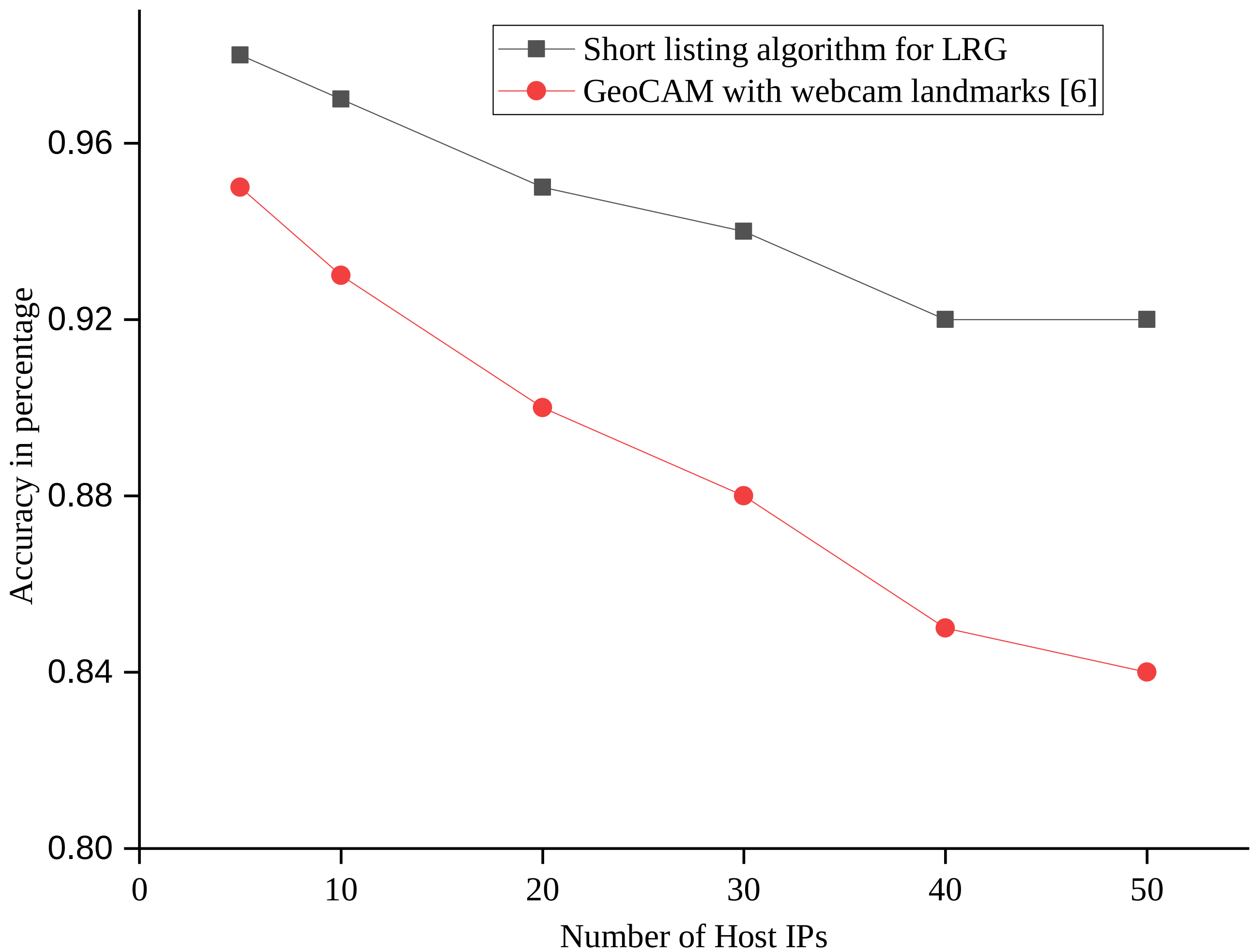


Figure 4.6: Accuracy of landmarks located near Target IP

6. **Accuracy of landmarks distance from the target**

The distances between used landmarks and the target are also assessed. The distance calculated from the Google map is compared with the declared distance of landmarks from the target. Section of Multilateration has already shown such a comparison for a single host IP. Within the same city, approximately, a landmark (217.7.205.3) is filtered out near the target (2.44.120.242). About 936 kilometers away. In general, landmark distances are evaluated at different distances from the target so that the accuracy of the measurements could be evaluated. This experiment is used the extracted landmark set to filter out landmarks under 1 km, 5 km, 10 km, 50 km, 100 km, 500 km, and 1000 km. Google Maps are used to measure the distance between landmarks to determine the accuracy of landmark distance claims.

Figure 4.7 shows the accuracy of landmark distance measurements toward the target in two different cases (LRG and GeoCAM). A different distance bracket is specified on the X-axis, whereas Y-axis represents the accuracy of each distance bracket. Nearby landmarks to target, under 200, 400, and 600 km, are fewer and more accurate, showing good accuracy. There are a good number of landmarks near Target IP under 1000 km, but there is a slight deviation in distance claims when cross-checked with Google Maps for distance. There is a slight loss of accuracy, resulting in a 96% accuracy. Using the short-listing algorithm and delay-distance conversion, the distance between landmarks and the target is extracted, and multilateration is performed to obtain the feasible region of the target IP. The error rate between the actual target IP and experimented target IP is very less nearly 4% and the accuracy rate due to the very less error rate is 96% for the target IP. Figure 4.7 shows the comparison between LRG and GeoCAM.

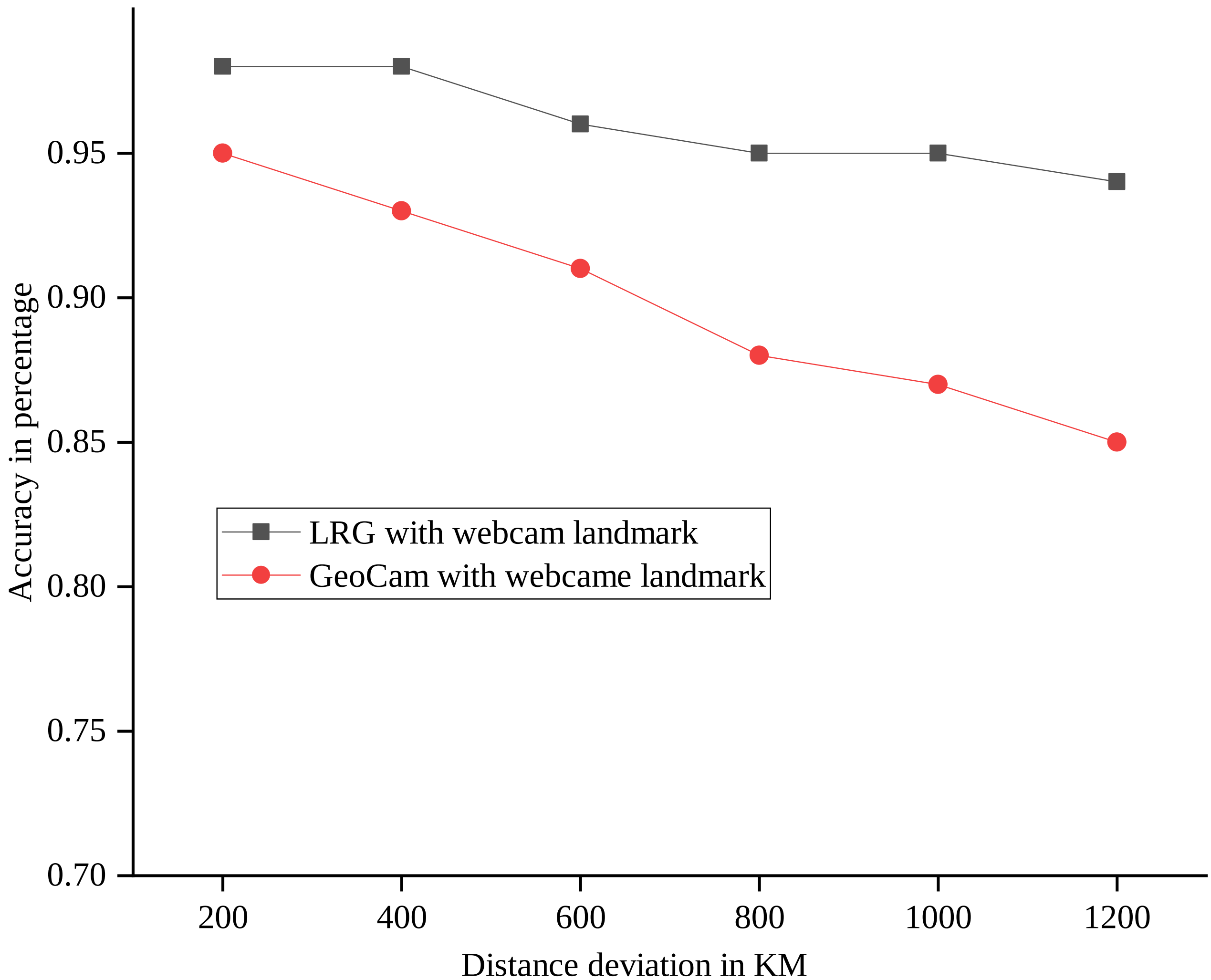


Figure 4.7: Comparison between LRG and GeoCAM

Chapter 5

5.1 Conclusion

The geolocation information associated with an IP address is useful for several specific Internet applications such as cyber security analysis, content delivery, product advertising, fraud detection, and prevention approaches. The mapping approach for true IP to geo-location plays a vital role in the protection of databases and software systems-based applications. The performance accuracy of such mapping approaches is directly impacted by delay-distance relations and limited visible landmarks among network entities. Several existing approaches, using trace route, ping, landmarks, and different mathematical models have been proposed to overcome such problems. Due to the dynamic nature of internet congestion, weak connectivity, and delays; achieving a high degree of accuracy in IP location mapping is an uphill task. Although, GeoCAM is a recent approach that adopted a delay distance relation between the target and landmarks to find the real IP to geo-location aimed with maximum accuracy. However, accuracy, reliability, and latency can be further improved based on the last router between the target IP and landmarks. This research study focused on the availability of promising high quality landmarks where online CCTVs are adopted as landmarks. This study proposed a multi-measurement (passive & active) framework that uses the Last Router geo-location (LRG) with a new algorithm for filtration. LRG IP to geo-location framework identifies the exact location of the target by locating the landmarks closest to it based on delay distance conversions. Extensive simulation results are conducted to find the precise location of a target IP with higher accuracy and reliability. By using passive and active approaches, the accuracy of the LRG framework is improved from 94.20% to 96%.

5.2 Future Work

Promising Landmarks

We can continue to work on this system by periodically checking for new landmarks and feeding them into the proposed database through the sync of the webcam landmark source (mentioned in the flow diagram).

Optimal Storing Time

Analyzes changes in IP addresses to determine the frequency of server changes [7]. We can determine how long IP to geo-location results last by measuring their location on average and whether their information should be kept. For future research, this would be useful.

Information of Routing and Border Gateway Protocol (BGP)

BGP (Border Gateway Protocol) -Router information for packets between Autonomous Systems (ANs). In addition, BGP information can also be used to cross-verify geo-location results by filtering landmarks in the initial stages, before even selecting landmarks. As an example, if an AS announces an IP address (netblock) for China, then it is very likely that this IP address is likely to belong to a Chinese host.

An intermediate hop graph (routers) and their countries can also provide useful routing information. To extract such routing information, trace routes can be performed to IP addresses with known locations. Then intermediate hops can be assigned countries based on the IP address where the traceroute tool lives. Likely, an intermediate hop that forwards packets only to hosts in Italy is located there. Trace routes can be performed recursively for verification and for constructing a graph of intermediate hops. This idea is not researched in this project, but future researchers can explore it. There is a lot of potential and interest in this case.

Use of More Servers (Monitors)

In the future, anyone who wishes to implement this system should consider using fast servers in different locations as monitors. As the number of monitors increases, more traceroute measurements will be made from different pinpoint locations, which will result in better landmark filtration.

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Target IP : 2.44.120.242
Active Measurements started:
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Fetched Landmarks : 32

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Filtered Landmarks

[1564887396, 1564948898, 3168278730]

Short-Listed Landmarks

[1564887396: 18, 3168278730: 12, 1564948898: 10]

Trace route Details for delays between last router and landmarks:

['93.70.73.99': 144.703, '188.216.24.202': 134.7896, '93.71.57.162': 127.64000000000001]
details (Km) converted from delay details:

[('93.70.73.99', 43410.9): (45.4581, 7.87192), ('188.216.24.202', 40436.8): (45.81, 9.08744), ('93.71.57.162', 38292.0): (45.6678, 8.17961)]

City Level details:

['2.44.120.242' :'Unknown' , '93.70.73.99' : ' Ivrea','188.216.24.202' :'Como parking view','3.71.57.162': 'Pratrivero s.p.a']

Process finished with exit code 0

Target IP : 124.102.245.152
Active Measurements started:
...*.*...............*.*....................*......*......

Fetched Landmarks from Database : 2142

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Landmarks with matched hops : 336

[2087122328: 8, 2575523682: 8, 1925155152: 7, 2579083276: 7, 2110665243: 7, 1981123797: 7, 2110288036: 7, 2579248706: 6, 3684792748: 6, 1009240869: 6, 3698186596: 6, 3020932611: 6, 3021411492: 6, 2579063058: 6, 2077845973: 6, 2047989155: 6, 1981124329: 5, 1924717057: 5, 3534011979: 5, 1922987783: 5, 1923347719: 5, 3685064353: 5, 2577742699: 5, 2110375215: 5, 2037876965: 5, 2577972241: 5, 2579780656: 5, 2078345874: 5, 3024036040: 5, 3021888148: 5, 2082004899: 5, 3023771037: 5, 2037877720: 5, 3705349096: 5, 1009270826: 5, 466257585: 4, 2576226979: 4, 659128581: 4, 2937219897: 4, 2581354396: 4, 1941000856: 4, 1980734561: 4, 3023694680: 4, 3698190333: 4, 3022022242: 4, 2575487558: 4, 1696842733: 4, 979036341: 4, 2055649662: 4, 1924759999: 4, 465692316: 4, 1008866253: 4, 2577202961: 4, 659190575: 4, 3020965227: 4, 3533945761: 4, 3538060236: 4, 466282183: 4, 453961896: 4, 3657947216: 4, 3704719912: 4, 2487542304: 4, 3539613715: 4, 2581674378: 4, 2110253061: 4, 2580829127: 4, 1009761796: 4, 1009301353: 4, 1924015657: 4, 3021933966: 4, 2055512198: 4, 1981127319: 4, 3404193346: 4, 3022313372: 4, 466945453: 4, 1924386191: 4, 3022682382: 4, 2581358821: 4, 3019975096: 4, 3021822715: 4, 3720568618: 4, 3697311926: 4, 1037027718: 4, 3735213125: 4, 2576252530: 4, 453872092: 4, 2031109663: 4, 2244705896: 4, 2580568492: 4, 2580605312: 4, 2579141923: 4, 1320930234: 3, 3532177963: 3, 1144527799: 3, 1229244883: 3, 406742562: 3, 854267553: 3, 1227370371: 3, 1180221694: 3, 1796355469: 3, 2913319482: 3, 1166903682: 3, 1659488906: 3, 973190562: 3, 1144885067: 3, 1981159353: 3, 1206612807: 3, 1657449220: 3,

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Filtered Landmarks

[2575523682, 2087122328, 1925155152, 2579083276]

Short-Listed Landmarks

[2087122328: 110, 2575523682: 85, 2579083276: 60, 1925155152: 52]

Trace route Details for delays between last router and landmarks:

['153.131.96.98': 105.96650000000001, '153.185.176.12': 93.1625, '114.191.137.80': 96.69960000000001]
details (Km) converted from delay details:

[('153.131.96.98', 31790.0): (32.783, 129.867), ('153.185.176.12', 27948.8): (36.7, 137.217), ('114.191.137.80', 29009.9): (33.5539, 130.198)]

City Level details:

['124.102.245.152' :'Unknown' , '153.131.96.98' : ' Pictimo','153.185.176.12' :'Toyama','3.71.57.162': 'Itoshima']

Process finished with exit code 0

Mapping Approach for True Internet Protocol geo-location Information using Active and Passive Methods

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