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Broadband Internet Speed Dashboard for Sustainable Service Improvement in Thailand

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***Abstract*— The measurement of broadband performance is vital for consumers, ISPs, regulators, and policymakers. The speed of broadband access services poses a challenge for managing end-user performance expectations and for regulatory policy. This paper centers on visualizing broadband speed data, particularly in Thailand, to assess the speed of Thai broadband services. We've developed a dashboard that visualizes and categorizes speed information by location, time, ISP provider, and internet package, providing valuable insights for decision-makers. Our dashboard can show internet speed rate issues compared to the upstream signal. Additionally, it can be used to observe, monitor, and provide evidence of sustainable improvement in light of the increased availability and use of better broadband.**

Keywords—broadband internet speed test, visualization, dashboard, sustainable

I. INTRODUCTION

Broadband performance measurement is an ongoing challenge for policymakers. Many participants in broadband services want to know the speed and spatial coverage. Over the past three decades, Internet speeds have evolved from kilobits and megabits to gigabits [1-3], signifying a substantial transformation in the digital connectivity landscape. The COVID-19 pandemic [4] has further accelerated this transformation.

A comparative analysis of internet user data across Asia's population proportions in 2022 [5] reveals noteworthy insights. The top five countries that exhibit the highest rates of internet adoption are South Korea (97%), Japan (93.30%), Philippines (91%), Thailand (88.30%), and Vietnam (86%). Notably, Thailand has experienced an extraordinary surge in Internet users, with a 26.9-fold increase, equivalent to 62 million individuals for 2022, as detailed in Table I. This substantial growth in internet usage within Thailand can partly be attributed to the strategic policies that the National Broadcasting and Telecommunications Commission (NBTC) has implemented since 2013. These policies have strategically focused on expanding essential telecommunication services nationwide, playing a pivotal role in fostering this growth.

An examination of the Internet access data within Thailand, based on the ITU World Telecommunication indicators for 2019, as reported by the NBTC, reveals that the rate of access to fixed-broadband subscriptions per 100 individuals is 14.9%. This statistic underscores a persistent upward trajectory in internet adoption [5].

TABLE I. STATISTICS OF ASIA INTERNET USAGE IN 2022

Country	Population (2022 Est.)	Internet Users (Year 2000)	Internet Users (Year 2022)	Penetration % Population
South Korea	51,340,112	19,040,000	49,799,909	97.00%
Japan	127,202,192	47,080,000	118,626,672	93.30%
Philippines	111,987,776	2,000,000	101,900,000	91.00%
Thailand	70,082,569	2,300,000	61,900,000	88.30%
Vietnam	98,745,016	200,000	84,919,500	86.00%

To enhance the efficiency of national-level Internet services, it is crucial to establish a framework that measures and evaluates the quality of Internet service received by the public. Speed is the primary indicator for assessing the 'quality' of broadband services. A comprehensive understanding of broadband quality plays a pivotal role in shaping regulatory policies, influencing end-user behavior, guiding marketing strategies, managing data transmission, and aiding decision-making for network service providers. Therefore, grasping how to measure speed comprehensively is paramount [5, 6].

Once performance measurement is accomplished, the next critical step involves the analysis of emerging issues. Tools that facilitate clear and straightforward spatial analysis of issues in specific areas become indispensable. Such analysis is predominantly achieved through spatial visualization. It effectively helps uncover and address challenges. Research in

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visualization [7] has proposed a method for analyzing broadband data in rural areas, emphasizing a bottom-up spatial analysis approach. This involves the initial collection of data at the local level before consolidating it at the national level, departing from the conventional top-down approach. The findings from this analysis are then conveyed through maps and data. Local and dynamic elements considered for analysis include the relationship between connectivity patterns in rural census areas and the types of connections present at the regional level (data on urban and suburban communities). This approach aligns with the methodology employed in previous research [8], which reveals the spatial distribution of average download and upload speeds, aiding in the understanding of service speed trends and the analysis of quality issues within local broadband infrastructure. Some reports [9, 10] employ maps and heatmaps to illustrate examples of service speed, facilitating spatial comparisons. Certain studies [11, 12] have even proposed prototypes that support visualization and real-time monitoring while processing and displaying extensive datasets. The significant achievement of this research lies in demonstrating the potential of dashboards to identify trends, seasonal events, and abnormal behaviors, thus providing insights into the information. Similarly, some objectives of dashboards are an integration of geographic visualization for decision support, real-time monitoring, and increased productivity [13-15]. Nevertheless, ongoing monitoring is essential for information management companies operating in highly competitive environments requiring rapid, intuitive, and easily comprehensible analysis of generated business data. Dashboards, therefore, serve as a reporting form that allows monitoring indicators relevant to the business. For Thailand's broadband speed testing system, most service providers have their own systems for testing. Such systems cannot store history, thus making it impossible for NCBT or users to view historical data for improvement or make future decisions.

This research aims to develop a broadband speed testing system to visualize statistics of broadband speed tests by integrating maps to describe speed test rates each time of the day. Also, it enables comparing the speed in different areas and providers. Moreover, the proposed dashboard will display the history of broadband Internet speed of users or areas and reveal the areas where broadband Internet speed does not reach the expected value.

II. Literature Review

A. Dashboard Concepts

Dashboards serve as essential tools for business management by consolidating and presenting key performance indicators (KPIs) to facilitate informed decision-making, as articulated by Stephen Few [16]. In his definition, a dashboard is a visual display of critical performance metrics to achieve specific objectives. This real-time interface condenses information onto a single screen, featuring tools like filtering and drill-down graphs for enhanced usability. Stephen Few emphasizes that a well-designed dashboard can create an efficient organizational image. It should showcase current data and incorporate historical data, highlighting values that significantly impact the organization and contribute to a clearer understanding of trends. In the context of business decision-making, adopting dashboards offers entrepreneurs a powerful tool to analyze strengths and weaknesses comprehensively [16]. Therefore, integrating dashboards into business practices is crucial for enhancing analytical capabilities and overall business improvement.

B. KPI for Visualization

The dashboard is a tool for visualizing information that monitors, analyzes, and displays key performance indicators (KPIs), and key data points [16]. Dashboards enable both technical and non-technical users to understand and apply business intelligence to make better decisions. Our proposed dashboard commits to 5 KPIs including:

1) Revelation of the areas where broadband Internet speed does not reach the expected value

2) Comparing the speed in different areas, providers, and each advertised speed package

3) Showing speed rates and comparing them at each time of the day

4) Filtering the target for interesting information

5) Display the history of broadband Internet speed by user or areas

C. Dashboard Characteristics for Broadband Speedtest

An effective broadband speed test dashboard is characterized by its ability to seamlessly deliver real-time performance insights, presenting users with clear and concise information about their download speed, upload speed, and latency [1, 3]. A user-centric interface ensures that even complex speed metrics are communicated in an intuitive and visually appealing manner, facilitating quick comprehension of broadband performance. The inclusion of historical trend tracking allows users to monitor the evolution of their connection over time, while geographic and network context features provide insights into server connections and regional influences on speed. In essence, an optimal broadband speed test dashboard combines real-time feedback, user-friendly design, historical tracking, contextual insights, and robust diagnostics to offer users a comprehensive and actionable view of their Internet connection.

III. Methodology

This research involves developing a broadband Internet speed dashboard to present the results of testing the quality of broadband Internet signals from service providers in Thailand. The evaluation utilizes four key indicators: DPA (Download Percentage Average), UPA (Upload Percentage Average), Ping, and Jitter. The dataset for the dashboard is derived from 30 devices and 200 volunteers located in the eastern region of Thailand, spanning the period from June 1 to August 31, 2023.

A. Criteria for classifying the quality of Internet service

Considering indicators of DPA, UPA, percentage of the equipment's ability to measure the signal continuously

Identify applicable funding agency here. If none, delete this text box.

(Continuity: C) or percentage of network stability (Network Reliability: NR) divided into 4 levels as follows:

- Excellent level, represented by values ranging from 90 to 100%.
- Good level, represented by values ranging from 75 to 89%.
- Moderate level, represented by values ranging from 50 to 74%.
- Poor level, indicated by values below 50% (requires improvement).

Criteria for classifying the quality of internet service when considering Ping are divided into four levels as follows:

- Excellent: Ping less than 20 ms.
- Good : Ping ranging from 20 to 50 ms.
- Moderate level (Fair): Ping ranging from 51 to 100 ms.
- Poor Level: Ping exceeds 100 ms (requires improvement).

B. *DPA (Download Percentage Average), UPA (Upload Percentage Average)*

In the presentation of speed data, the need for standardization becomes evident. This necessity arises because users subscribe to various broadband packages with differing rates. Researchers propose a normalization process for Internet speed measurements obtained from all tests to enable a fair and meaningful analysis and comparison of test results. This involves calculating the daily or 24-hour average speed and comparing it to the speed corresponding to the user's subscribed package. The result is expressed as a percentage, indicating the proportion of the average speed compared to the speed specified by the subscribed package, denoted as the Download Percentage Average (DPA). The calculation is shown (1).

$$DPA = \frac{Average\ Download\ Speed\ in\ Hour}{Advertised\ Package} * 100 \qquad (1)$$

The method to calculate the percentage of the average upload speed compared to the speed from the package being used (Upload Percentage Average: UPA) is given in (2).

$$UPA = \frac{Average\ Upload\ Speed\ in\ Hour}{Advertised\ Package} * 100 \qquad (2)$$

C. *Data Preparation*

Data obtained from the Internet signal quality test exclusively comes from Internet speed measuring equipment. Volunteers' Internet speed test results are transmitted from the docker server to a PostgreSQL database at the server center every 1-2 minutes to ensure the platform's data is continuously updated. We divide the volunteers into 5 clusters using hybrid partition clustering [17]. This method combines three techniques: partitional clustering, proportional allocation, and center-of-gravity. For this reason, we ensure that the distance between the volunteer and the server to identify the applicable position of established cloud servers to support the testing of a high-speed internet platform. Given that these data values are raw and may contain anomalies, such as unusually low or high test speeds or zero download/upload values, a preliminary step involves transferring the data for extraction, filtering, and cleaning before it can be effectively visualized.

The research platform is designed to connect to a PostgreSQL database, which was chosen for its support of NoSQL data types and text search types, which provide ease of data search. The transformed data is stored, set aside, and prepared for subsequent use.

D. *Components of Broadband Dashboard*

1) Collection Data Design: The database design focuses on presenting the quality of broadband internet service. The data collection section accommodates both Internet speed measurement devices and volunteer data.

a) Speed test devices data: The device information collected for internet speed devices includes the device ID, timestamp, operator name, server name, location (district, province), longitude/latitude, download/upload speed package, download/upload actual speed, ping, and jitter.

b) Volunteer data: The volunteers provide Name, telephone number, address, longitude/latitude, connection type (WIFI/Cable), provider name, download/upload speed package, timestamp, download/upload actual speed, Ping, and jitter.

2) Broadband dashboard design: The dashboard presentation of the Internet signal quality test is designed to cater to different user perspectives:

a) Admin view: Displays information in two views - device view and user perspective including summarizing data and presenting various graphs with information such as the number of Internet signal measurement devices/total users, the proportion of devices/users compared to the total number used by the provider, and the percentage of average Internet speed relative to the maximum speed promised by service provider. Graphs showcase average, maximum, and minimum download speeds, together with upload, ping, and jitter speeds for each area and time. A map displays the latest test results according to devices' and users' latitude/longitude coordinates.

b) Provider view: This view is exclusively accessible to the Internet service provider. The data view offers a comprehensive breakdown of download, upload, Ping, and Jitter averages, organized by location and user over time. Providers can also visualize user details on a map based on location, latitude, and longitude. This design allows providers to monitor the outcomes of their Internet user tests in real-time. Moreover, this information is invaluable for strategic planning, enabling providers to enhance the quality of Internet service in the respective areas in the future.

c) User view: Individual users have personalized access to their Internet test data and history by logging in with their registered username and password. Users can search for their latest or historical test results in map and table formats. This personalized dashboard offers a comprehensive breakdown of download and upload speeds, Ping, and Jitter over time. This user-centric design enables individuals to track and comprehend their Internet performance. Users can leverage this information for personal awareness and to provide feedback to service providers, contributing to continuous improvements in service levels.

E. Dashboard Functionality

The development of the data visualization dashboard has presented comparative data on the results of Internet signal quality measurements using four indicators, including DPA%, UPA%, Ping, and Jitter, from volunteers in the eastern region, which spans seven provinces: Chonburi, Rayong, Chanthaburi, Trat, Sa Kaeo, Prachinburi, and Chachoengsao.

The information displayed in this dashboard has undergone a cleansing process, with advertised packages divided into four groups based on download/upload advertised speed: less than 250 Mbps, 250 - 500 Mbps, 501 - 750 Mbps, and more than 750 Mbps. Users can choose the month for viewing data, with the information presented in a monthly summary. The results for each indicator are showcased as follows:

- Download/Upload speed: Comparisons in this indicator can be displayed based on user preferences, including the average download/upload percentage according to advertised speed, provider, and province.
- Data comparisons in the form of time averages , including each service provider's average download/ upload speed over 24 hours and during three periods: 6:00- 10:00 AM, 10:01 AM - 5:00 PM, and 5:01- 10:00 PM.

IV. Results

The collection of volunteer data for the execution of speed tests in Thailand encompassed seven provinces within the eastern region: Chonburi, Rayong, Chachoengsao, Prachinburi, Chanthaburi, Trat, and Sa Kaeo, covering a total of 30 districts. We selected such provinces as a prototype of our proposed system. The dataset comprises 17,125 instances, with Chonburi accounting for the majority at 53.08%, Rayong at 19.97%, and Chachoengsao at 7.05%.

This research focused on four network providers, denoted as A, B, C, and D. The percentages of Internet speed for download, ranked in descending order, were as follows: A (71.61%), C (70.44%), B (59.91%), and D (51.95%). Similarly, for upload speed percentages, the order from highest to lowest was A (79.41%), C (72.9%), B (71.42%), and D (55.02%). These figures provide a comprehensive overview of the distribution of speed test instances across provinces and the comparative performance of network providers.

A. A regional case: Eastern Thailand

The average internet speed percentages for each province are categorized by network. Our dashboard can filter four features: Download, Upload, Ping, and Jitter, as shown in Figure 1. It was observed that Network D in Chachoengsao, Sa Kaeo, and Chanthaburi provinces has average Internet speed percentages below 30% highlighting relatively low performance.

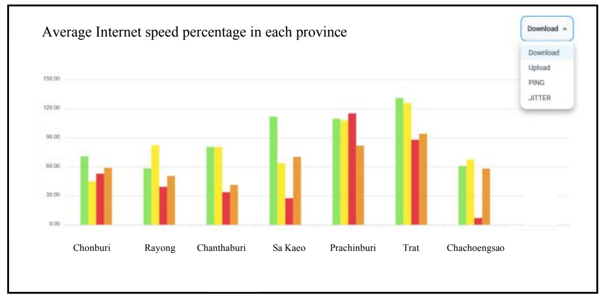

Fig. 1. Each province's average Internet speed percentage is depicted in a bar chart. The x-axis shows the province. The y-axis shows the average speed in percentage and by drop-down filter, including Download, Upload, Ping, and Jitter.

The bar chart presents the value of average Internet speed percentages in each time interval within a day, categorized by the network, as shown in Figure 2. Such a dashboard has four filter features: Download, Upload, Ping, and Jitter. The color of each bar chart represents ISP. The X-axis shows the time interval within a day, and the Y-axis shows the minimum and maximum average internet speed percentages, categorized by service providers.

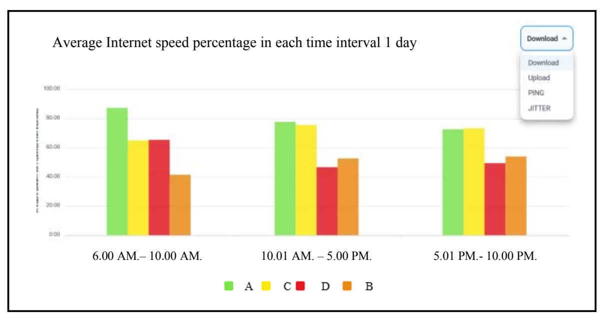

Fig. 2. The comparison of ISPs' average Internet speed percentage in each time interval of one day.

B. Interactive Map

Our dashboard provides users with a better experience than a table of numbers. We used an interactive map that users can use. They can zoom in, zoom out, click, and double-click into a map. The user can select the areas of interest as desired. The information of each user will be displayed on a pop-up text box that is used to display additional or supplemental information about the topic specified, such as name, package, and speed value. For example, when the user clicks the mouse to zoom in, the dashboard will show a circle and the number of users located in the area. The circle will be separated, and the number will decrease whenever the user zooms in more until the circle shows as the symbol or logo of the company that indicates the real location of information of speed test data. The information on the pop-up box shows real-time data such as location, coordinates, IP address, Upload, Download, Ping, Jitter, and the latest test data, as illustrated in Figure 3.

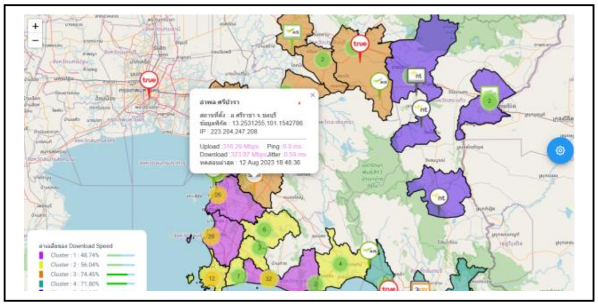

Fig. 3. The map shows seven provinces located in the eastern part of Thailand; the boundary with color depicts a cluster of areas of our research, and the circle shows the number of speed test data that are grouped in each area.

In addition to the geographical visualization offered within the dashboard, the functionality extends to enabling users to refine data presentation through various filters. These filters encompass parameters such as province, district, date range, service provider, and classification by type (e.g., user or device). Moreover, the dashboard employs a categorization scheme based on the average speed, classifying data into five distinct groups. This classification is graphically depicted in Figure 4 for clarity and reference.

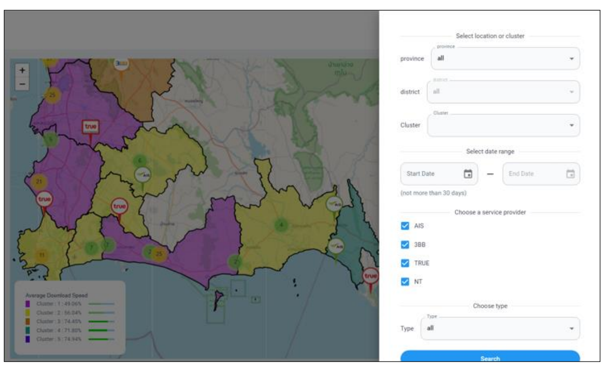

Fig. 4. The right-side dialog box shows filter options for searching by location and variables such as province, district, date range, and type. Additionally, it can cluster based on the average dashboard speed into 5 clusters.

C. Heat Map

The statistical graphs within this research paper facilitate a comprehensive exploration, providing insights from various dimensions. Primarily, these graphs scrutinize user perspectives by examining quality through nine distinct sub-views. These sub-views encompass comparisons between download and upload speeds across diverse factors, and the interactive dashboards enable data filtering based on five key features. Additionally, they depict the volume of datasets measuring Internet quality, offer province-specific insights into data collection volume, and elucidate differences among tester groups. Notably, interactive Heat Maps visually represent download and upload speeds, utilizing color differentials to signify variations in speed. Furthermore, these graphs afford a perspective on average upload and download speeds (UPA and DPA). A secondary viewpoint is applied to assess quality based on devices, with two sub-views exploring download and upload speed perspectives.

Examining Figure 5, the heat map depicting average download speed reveals that ISP Network A consistently maintains a favorable range of speeds across nearly all-time intervals. Network C follows closely, displaying a commendable speed range from 7:00 AM to 11:00 PM. Meanwhile, ISP Networks D and B exhibit lower speed ranges than the other networks. This dataset serves as valuable information for each Internet Service Provider (ISP) to optimize strategies, particularly during intervals characterized by lower download speeds.

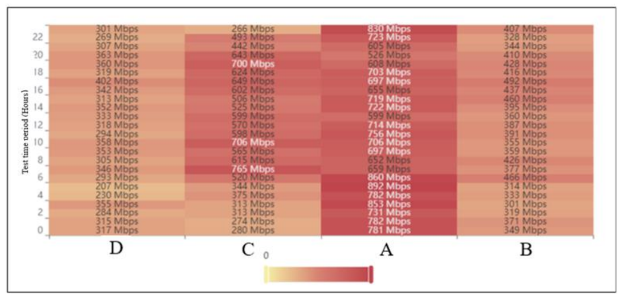

Fig.5. Heat map of download average speed. The x-axis shows the hour from 0 – 24. The range of speed is 0-892, as shown via bar scale.

It is evident in Figure 6 that most of the time, all networks exhibit an average upload speed surpassing or equal to 90%. Network A emerges with the highest frequency in this category, succeeded by networks B, C, and D in sequential order. Conversely, networks with average upload speeds falling below 25% include network D, trailed by networks A, B, and C in descending order. This observation highlights the networks that should improve their upload speed.

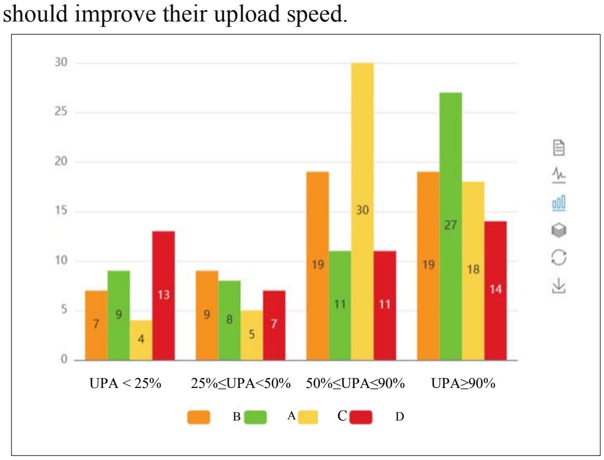

Fig.6. A bar chart of the average upload speed.

Figure 7 shows a dashboard that allows filtering date ranges for download and upload activities, revealing peak and off-peak service usage times. From the perspective of Application Service Providers (ASPs), this data is beneficial for allocating resources appropriately during high-demand periods, ensuring maximum service readiness. For Internet Service Providers (ISPs), this information aids in network data transmission management, facilitating bandwidth allocation and service planning aligned with usage patterns. This enhances service efficiency during high-demand periods for users.

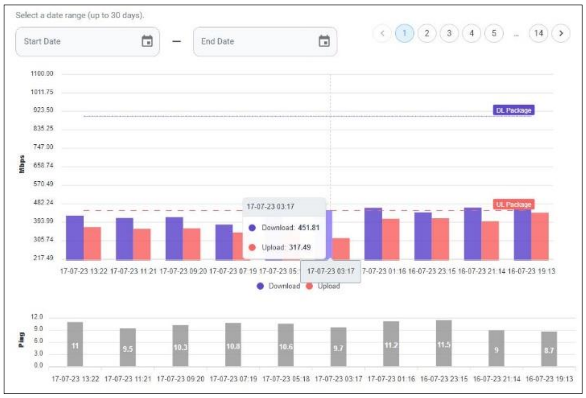

Fig.7. A bar chart of Ping separated by date ranges and a bar chart of download and upload separated by date ranges.

V. Conclusion and Future Work

We developed a broadband speed test system to comprehensively assess of broadband speed by integrating geospatial dashboards and statistical information. The findings indicate that broadband speed test dashboards show promise in effectively monitoring Internet speeds in specific geographical areas. Our proposed dashboards align with urban sustainability objectives and the principles of new management, presenting a robust knowledge communication tool for broadband speed tests. Additionally, we identified common design elements for data analytics dashboards, encompassing graphical user interface (GUI) styles and conceptual models of performance indicators. Future work will delve into issues related to data streams and address the challenges big data poses. The system architecture will consider data compression techniques for real-time visualization when implementing speed test applications across all provinces in Thailand. These enhancements are essential for providing real-time information and enhancing user interaction. Moreover, forthcoming research will explore the advantages and disadvantages of our proposed dashboard technologies. As these dashboards aid decision-makers in comprehending internet speed issues for service improvement and given that the challenges outlined in this paper are addressed, the opportunities presented by geospatial dashboards can be extended to create sustainable tools for monitoring Internet speed tests throughout Thailand.

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