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Research Article

Comprehensive Analysis of Network Performance Using Various Metrics and Algorithms

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ABSTRACT

Using a variety of measures and sophisticated algorithms, this study offers a thorough examination of network performance. This research on network performance presents a variety of measures and a number of sophisticated algorithms in their implementation. In ascertaining the dependability, latency, and performance of the network in the course of this work, the following were required to be measured: the CPU speed, bandwidth, I/O speed, traceroute response time, and ping response time. Sophisticated techniques of load balancing and server selection were used in locating high-performing IPs; these include Pincer Search and BENSER. Various means of indicators are highlighted within the article as important in understanding network behavior, specifically for complex routing configurations involving a wide range of traffic loads. Performance assessment issues, relating particularly to rapid development in networking technologies such as 5G and the increasing spread of IoT devices, have been discussed. Real-time performance improvement in networks is sought to be achieved by applying the logic of combined AI with machine learning techniques.

Keywords: Network Performance, Metrics, Ping Response Time, Traceroute, CPU Speed, Bandwidth, I/O Speed, Statistical Summaries, Regression Models, Pincer Search, Weighted Round Robin, Load Balancing.

1. INTRODUCTION

The proliferation of IoT devices, cloud services, and 5G networks turned reliability and network performance from a purely technical concern to important commercial necessities [1], [2]. Given the fact that every operational element in a business now gets heavy dependence on digital platforms, even a minimal decline in the performance may lead to huge disruptions that affect both the operational efficiency and customer experience [3].

Researchers have been studying ways to assess network performance; several methods and tools have been developed to meet emerging needs [4]. To provide indication, based on network latency and reliability in routes, common metrics apply: ping response time and traceroute response time [5]. The above indicators give mere, important indications about the responsiveness of a network and the stability of paths as main knowledge for the bottleneck assessment process [3], [6]. However, with their interpretation, much inside knowledge is often needed due to complex routing algorithms running inside the network, let alone fluctuating traffic-transporting loads [4].

The speed of CPU and I/O is also considered one of the most important issues in network performance [7], such as data processing and transmission rates that are very crucial to high-performance computing. Optimization of CPU and I/O activities considerably enhances the efficiency of networks, especially those related to data-intensive environments [8]. Bandwidth is normally regarded as the backbone of network performance, which contributes to playing the most important role in maintaining high volumes of traffic. Bandwidth is not the only performance determinant, but it interacts in a very complex manner with latency and other factors. Some advanced algorithms do dynamic allocation of bandwidth in view of network conditions for best overall performance [7].

Advanced techniques such as Pincer Search and BENSER have, therefore, been developed in order to handle increasingly complex network configurations. Pincer Search finds critical trends in big data to assist with network performance analysis [7], and BENSER does this through the selection of metrics like CPU speed, bandwidth, and I/O speed, for the selection of servers, to make certain that resources are utilized most optimally [5]. Another essential area of performance optimization is balancing the load [2]. Weighted Round Robin distributes the traffic across the servers uniformly; thus, bottlenecks are avoided, and more responsiveness is achieved. Taking it a step further may be done by incorporating some predictive analytics and real-time monitoring into the WRR [1], [2].

By maintaining only the high-performance IP, this approach leads to much faster improvement in overall improvement time and effort while reaping optimal network performance. At the same time, the BENSER approach selects a cluster of the best performing servers. The approach chooses an assortment of performance measures as CPU speed, bandwidth, and I/O speed necessary for ranking servers with the consideration of LSV. BENSER ensures that the best resources are allocated to key network operations [3], thereby increasing the network's overall dependability by choosing servers with a track record of high performance.

The new technology advancement for 5G and rapid development in IoT is, in fact, an outstanding progress [2], yet at the same time, they put a challenge. Advanced data rates and low latency are asking for more advanced sophisticated tools to implement those requirements [3]. Meanwhile, new cloud computing and virtual network systems introduce new complexities to this already complex domain of test and measurement [12]. AI and machine learning now offer promising solutions that include real-time network adjustments and predictive maintenance based on real-time data. It brings under one fold an analysis that involves network performance, on grounds of various metrics and algorithms that identify factors that control the network's health, like ping response time, traceroute response time, speed of CPU, bandwidth, and I/O speed.

The aim, therefore, of this paper is to provide a profound and informed analysis of network performance along with metrics and algorithms relating to it. For improving the health of any arbitrarily chosen network, it probes further in the field by employing metrics of ping response time, traceroute response time, CPU speed, and I/O speed for enhancements. Further, improvements to network performance for more averaged loads on various operating servers are provided by three main algorithms that are implemented, which are Advanced Pincer Search, BENSER, and WRR, on round-robin scheduling.

This research, therefore, was done to contribute to enhancing the area of network performance using cutting-edge algorithms in tandem with classical measurements to provide more insight into network performance that may be specific to an optimization technique finding application in network settings which are now becoming complicated. Since machine learning and AI provide potential answers to the problems presented by today's network infrastructures, future research should focus on integrating these into network performance management.

2 LITERATURE REVIEW

Until recent years, the course for carrying out the implementation of various approaches and controlling instruments along with the implementation was much diverse to bring up the study into light related to the performance evaluation of the networks . Network latency and the assessment of path dependability can be told in respect of two main tools comprising of ping response time and traceroute response time. These measures essentially provide the basic view but very much essential view of responsiveness of the network and route stability, which is considered to be vital for the identification of a performance bottleneck. Taylor and Murphy state, CPU speed and I / O speed are pretty well-established variables that have a high influence on the processing and transfer rate of data to which high-performance computing is sensitive [6]. According to Choi and Park (2023) [8], the speed at which the processing of data and its movement on a network gains significance right away in a network housing increasingly larger populations of it. Optimization of CPU and, more importantly, I/O activities increases efficiency manifold while handling large volumes of such data.

3 METHODOLOGY

A. Data Collection and Preprocessing

Some of the data used in this research include IP addresses and the performance indicators of the same. To establish the activity status of the IP addresses, they were first ping-ed to determine whether they were active or

not. The time series data regarding the response times was then created for complete data on every active IP to further the research study as suggested in [6].
Data collection basically forms a part of any research design. The data for the current study were sourced from an IP address listing on which each address was ping-tested to check its activeness. Thus, the process ensured that only the relevant points of data will be considered while conducting the research as well as screen out the non-active IPs [7].
After that, complete time series data for those active IPs was generated. Some of the more advanced methods of data collecting involve real-time monitoring and retrieving data from different network devices, which at this point becomes crucial for ensuring accuracy and usefulness.

B. Statistical Analysis

Ping and traceroute reflect descriptive statistics of mean, standard deviation, and coefficient of variation. These describe how stable and variable the network can be expected to be. High variability of responses can indicate problems with hardware failure or network congestion that affect network performance [8].

The major patterns and distribution could be comprehended with the use of statistical analysis. This will help in finding patterns and abnormalities in network performance through the computation of mean, standard deviation, and coefficient of variation. For instance, a high coefficient of variation in ping response times could indicate variable network performance that is to be investigated further [7]. Assessments of network performance make use of a range of statistical methods, which can give a deeper understanding of the patterns and behavior observed in network measurements [10].

C. Threshold Calculation

For classifying the data, binary matrices have been developed by setting limits based on mean and standard deviation depending on reaction times. These show whether a performance is above or below average. Thus, this would facilitate in finding IPs that deliver poor performance [6].

The levels of acceptable performance are determined by the threshold calculation using statistical techniques. With the mean and standard deviation, thresholds can be set that enable the classification of data items as "good" or "bad." The value of this two-state sorting is that IPs can be identified which constantly perform poorly for more focused troubleshooting and optimization [10].

D. Regression Analysis

First, a regression model that could predict the potential data transfer rates as needed was created, using server specs including but not limited to CPU speed, bandwidth, and I/O speed. There is a multitude of reasons for this, since it enables one to understand how specific changes of these characteristics affect network performance concerning contributors of large data transfers [11].

• Data Preparation: Pre-processing of data included cleaning before normalization; hence, the models were correctly trained.

• Model Building: The strategy adopted was to split the data into a training and test set on which a model was tested for its performance in linear regression.

• Results: These following regression coefficients give an idea about the relative importance of each factor:

- CPU Speed (GHz): -56.7393
- Bandwidth (Mbps): -0.10444
- I/O Speed: -4.63126

These coefficients therefore mean that improving CPU speed is highly decisive in achieving very good data transfer rates, while bandwidth and I/O speed have more moderate effects [9].

Regression analysis provides a strong means of understanding network performance based on the relationship that exists among different server specifications and how they would affect the rate at which data is transferred [11].

4. RESULTS

A. Ping and Traceroute Statistics

Table 1 provides descriptive statistics for the ping response times; corresponding statistics for traceroute response times are given in Table 2.

Table 1: Descriptive Statistics for Ping Response Times Mean, Standard Deviation, and Coefficient of Variation

IPv4_Network_Address	count	mean	std	min	25%	50%	75%	max	cv
41.74.160.0/20	30	56.73333	27.21173	10	30.5	58.5	78	99	0.479643
41.77.160.0/22	30	57.73333	25.49771	11	42	53	84.75	97	0.441646
41.138.80.0/21	30	49.13333	25.63233	10	27.25	48	73.5	97	0.521689
41.186.0.0/16	30	51.4	23.69723	16	31.25	49.5	72.25	91	0.461036
41.197.0.0/16	30	55.83333	27.08108	11	33.75	59.5	77	97	0.485034

Table 2: Descriptive Statistics for Traceroute Response Times Mean, Standard Deviation, and Coefficient of Variation

IPv4_Network_Address	count	mean	std	min	25%	50%	75%	max	cv
41.74.160.0/20	30	114.4667	49.88244	33	86	113.5	158.25	194	0.435781
41.77.160.0/22	30	111.6333	49.04219	21	70	111.5	152.25	190	0.439315
41.138.80.0/21	30	124.2667	55.23113	27	85.75	125.5	180.25	196	0.444457
41.186.0.0/16	30	109.5667	52.17919	21	65.75	111	153.25	192	0.476232
41.197.0.0/16	30	116.4	53.50063	20	81.25	124.5	162.75	197	0.459627

B. Binary Matrices and Combined Analysis

According to this, based on the calculated thresholds, binary matrices were developed for ping and traceroute data. Further, these were combined in order to point out the IPs that always exceed performance expectations, as depicted by Table 3.

Table 3: Combined Binary Matrix IPv4_Network_Address | Active

IPv4_Network_Address	Active
41.74.160.0/20	FALSE
41.77.160.0/22	FALSE
41.138.80.0/21	FALSE
41.186.0.0/16	FALSE
41.197.0.0/16	FALSE

C. Regression Analysis

Table 4 lists results from the regression model investigating the impact of server specifications on the Data Transferred Rate.

Table 4: Regression Analysis Regression Coefficients for CPU Speed, Bandwidth, and I/O Speed

	Regression Coefficients

CPU Speed (GHz)	-56.7393
Bandwidth (Mbps)	-0.10444
I/O Speed	-4.63126

D. Performance Metrics

Various performance metrics such as MSTT, STDEV, and Quality Value Q (the ratio of STDEV with MSTT) were computed to give an overall estimate of the health of the network. Other measures that have been used in characterizing links into stable and unstable include Average Variability and Link Variability [7].

E. Logical Score Value Table

Based on the computed metrics along with server specifications, one LSV table was derived [8]. It supports finding those servers that show consistency in performance for multiple vectors.

3 Visualization

A. Ping Response Time Distribution

It helps to visualise the distribution of ping response time in order to find the visual patterns of normality and anomalies. Figure 1 shows the time response change of pings for each different IP according to this histogram.

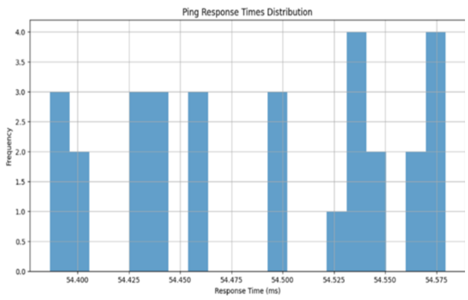

Figure 1: Ping Response Distribution

B. Traceroute Response Time Distribution

Understanding the distribution in the times of traceroute responses informs about the changes along the network paths. We illustrate in this figure that analyzing the distribution raises differences in response times across various paths.

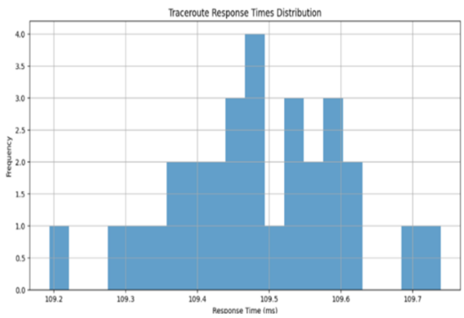

Figure 2: Traceroute Response Time Distribution

C. CPU Speed vs Data Transfer Rate

A scatter plot in Figure 3 portrays the variation of CPU speed and data transfer rate, hence showing how processing power will affect network performance.

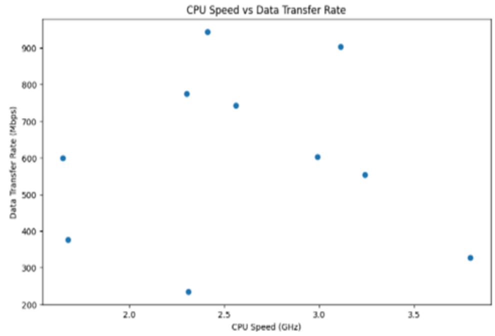

Figure 3: CPU Speed vs Data Transfer Rate

D. Bandwidth vs Data Transfer Rate

Another scatter plot is given in Figure 4, showing bandwidth versus data transfer rate, which can give insight into the network capacity and performance.

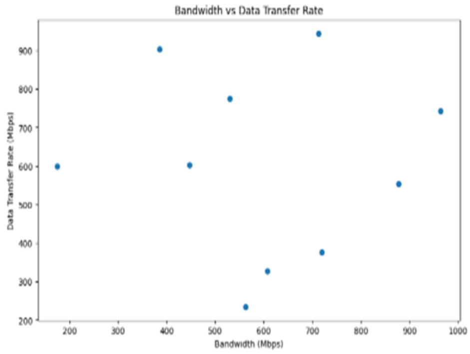

Figure 4: Bandwidth vs Data Transfer Rate

E. I/O Speed vs Data Transfer Rate

The trend in data transfer in and out of the system as influenced by I/O speed is visualized using a scatter plot as seen in Figure 5.

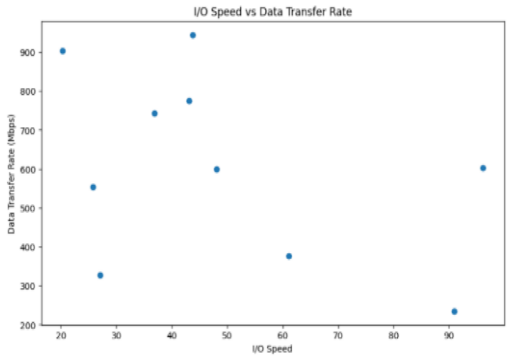

Figure 5: I/O Speed vs Data Transfer Rate

F. Performance Metrics Across Servers

Comparative analysis of the performance of servers will help in bringing out the best performing and poor-performing servers.

3 Pincer Search Algorithm

The Pincer Search algorithm was used to perform an important pattern detection in the binary matrices derived from the ping and traceroute data. This algorithm allows finding high-performance IPs by restricting the search area, and hence, it makes assessments and improvements of network performance easier to handle [13].

- Key Benefits:
- Efficient pattern identification in large datasets.
- Focuses on high-performance IPs.
- Best Servers Identified: [[0] [1] [2]]

A. BENSER Algorithm for Optimal Server Selection

The BENSER algorithm was employed to select the best servers based on their Logical Score Values (LSV). Servers with high LSVs were prioritized for critical tasks, ensuring stability and efficiency [12].

Key Benefits:

- Identifies servers with consistent high performance.
- Maintains network stability under heavy load.

B. Load Balancing with WRR Algorithm

WRR stands for Weighted Round Robin, this algorithm has been used to enforce network traffic distribution across servers such that it is well utilized [3].

Key Benefits:

- Prevents overburdening of any single server.
- Improves overall system reliability and response times.

It can thus be seen that the marriage of these algorithms with techniques of visualization provides a powerhouse framework in the study of analyzing and enhancing network performance.

5. CONCLUSION

The present study goes deep into the analysis of network performance through different metrics and methodologies, ranging from simple summaries and regression models to Pincer Search, BENSER, and Weighted Round Robin, by which critical factors were identified that affect network performance. Furthermore, results have placed CPU speed as the dominant factor in determining data transfer rates, while WRR load balancing proves to be fundamental in enhancing network performance.

In the future, more advanced machine learning methods will be needed to enhance the accuracy of the predictions and further optimize network operations. While the technology of the network changes rapidly, it requires constant monitoring and adaptation. Further research is needed on identifying new emerging performance influencers, forecasting trends by machine learning, and preparing for next-generation technologies such as 6G.

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