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Customized Ping Tool for Smart Grid Communication Network Testing

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***Abstract*—Heterogeneous and hybrid smart grid communication network is a network that comprises of different communication mediums and technologies. Performance evaluation is one of the main concerns in smart grid communication system. In any smart grid communication implementation, to determine the performance factor of the network, a testing of an end-to-end process flow is required. Therefore, an effective testing tool plays a crucial role in evaluating the performance of smart grid communications. Ping is currently one of the most widely used tools. In this paper, a customized ping utility, called Smart Grid Ping, is introduced. This utility provides random ping intervals with user selectable distribution, allowing network administrators to test the reachability and availability of various applications in smart grid communication system.**

Keywords-Smart Grid; ping; ICMP; network performance; reachability; random traffic

I. INTRODUCTION

Over the past few years, smart technologies have drawn a lot of attention among researchers, especially the term "Smart Grid" has become more and more popular. Smart grid has recently emerged as the next generation of electric power system which can solve the unique needs for effective communications, monitoring and controlling. It is a modernized electricity distribution network that consists of diverse applications supported by different communication technologies. Since smart grid is a complex system which comprises of various intelligent devices coexisting on the same network [1], the communication system built on top of smart grid infrastructure is normally a heterogeneous and hybrid paradigm. This communication paradigm is needed to ensure a two-way flow of electricity and information between the power plants and appliances [2] [3].

In smart grid communication network, information flows in two-way direction. Since the network is made up of a variety of communication devices, the network traffic is one of the main concerns when evaluating the network performance. Currently, there are a large number of tools and utilities available with different functions to serve different purposes. However, diverse communication technologies in smart grid creates major challenges for conventional testing software, for legacy testing programs are designated only for a single communication technology or standard in the network. Due to the heterogeneous and hybrid communication paradigm of smart grid, the type of network traffic is still an unknown. The constant traffic no longer reflects the real traffic in multi-technology bi-directional communication. In addition, high availability is one of the standard requirements in most communication systems. Devices within the network should be reachable under all situations [4]. Therefore, a customized ping tool, named Smart Grid Ping, is implemented in this paper to generate random traffic and to test the network reachability, allowing administrators to analyze and evaluate the network performance of a heterogeneous and hybrid smart grid communication system.

This paper is organized as follows. Section II outlines the objective and scope of the project. Section III provides a brief overview of smart grid, ping utility as well as previous works from the related area. The methodology for implementing Smart Grid Ping will be presented in Section IV. The results are discussed in Section V. Finally, Section VI concludes the paper and proposes some possible future works for the PING tool.

II. OBJECTIVE AND SCOPE

A. Objective

The objective of this research paper is to develop a customized ping tool to generate random traffic as well as to test the availability and reachability of various devices in Smart Grid communication network.

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B. Scope

The scope of this project is to implement the testing software for TNBR-Uniten smart grid testbed.

III. BACKGROUND

A. Smart Grid Testbed

Smart grid comprises of several systems, including SCADA (Supervisory Control and Data Acquisition Systems), EMS (Energy Management Systems), DCS (Distributed Control Systems) and AMI (Advanced Metering Infrastructure). Devices that are used to support these systems consist of RTU (Remote Terminal Units), PLC (Power Line Communication) modems, smart meters, data concentrators and so on.

Wired and wireless are proposed as communication mediums for smart grid. The communication technologies that support the network include Power Line Communication (PLC), unlicensed Radio Frequency (RF), and WiMax/4G as shown in Figure 1. PLC is one of the common technologies used to transmit data over wired network. However, the transformer normally blocks the data signal and hence the PLC technology is restricted between transformers [5]. Thus, besides wired technologies, wireless can be used as a solution. For example, RF mesh is suitable to use in smart metering applications [6], and WiMax/4G can also be used for inter-substations and backbone. Most smart grid implementation is based on open standard and TCP/IP is the dominant one.

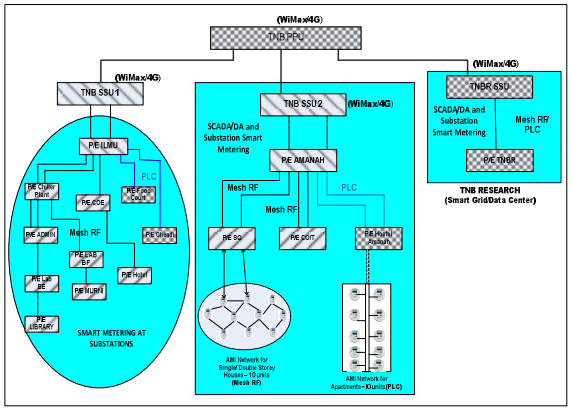

Figure 1. Smart Grid network design.

B. Ping

Ping [7] is one of the most common tools used to test the availability and reachability of a host on an IP (Internet Protocol) network. It acts as an administrator utility which can identify if the targeted host is reachable or not. Ping operates by sending Internet Control Message Protocol (ICMP) packets, or echo-requests, to the destination host and wait for an ICMP response, or an echo-reply. During the process from transmission to reception, the time taken is measured as round-trip time, and packet loss is recorded. The ping packet is considered lost if it does not receive back a response or it has timed-out.

Once the ping command has been successfully released, the obtained results will be summarized in the ping statistics. The number of packets sent, received, percentage of packets lost and round-trip time will be displayed in the output. Ping can be used not only to test the reachability of a host, but also to record the route taken or to generate network traffic. With these functions, ping can be used as an effective tool to analyze and assess the performance of smart grid communication network.

C. Related Work

As mentioned in [8], smart grid testbed design and implementation can be assessed by quantitative evaluation, which provides empirical data. The quantitative evaluation of the testbed deals specifically with the performance of the network emulation. Throughput and latency of network emulation can be evaluated using software tool such as ping.

Ping was also used in [9] as a tool to measure the round-trip time for several IP technologies in smart grid, including ADSL, WiMax and 3G/GPRS. A number of tests were set up using ping by sending ICMP echo-requests and waiting for echo-replies. After several weeks, the latency for each technology was recorded and compared to evaluate if they are able to meet the performance requirements of smart grid applications or not.

Similarly, latency tests were carried out in [10] in order to analyze smart grid communication network. A test setup was build, consisting of a router, an Ethernet switch, PLC modems and several computers. Ping tests were performed for the latency analysis in the test setup. It is an important parameter especially in the protection applications.

One of the ways to protect an electric power system is to avoid outages. In [11], ping was used to confirm the locations where meter outages happen. After pinging the meter, its response time will be considered to validate the outage event, and the energized state of AMI meters can be checked using on-demand pings.

In addition, [12] described ping as an effective tool in testing the communication availability of GPRS, a technology often used as intermediate between the concentrator and the front end. The tests were conducted to check if the communication is working or not.

From the overview of the related work above, ping appears to be widely used for network testing in smart grid. However, the approach used to evaluate the system performance in [8] is based on a representation of the system behavior through a model. In other words, the network testing was performed using network emulation or software simulation tools. This approach has a major drawback of oversimplification of the actual scenarios. Nevertheless, the ping utility implemented in this paper is used to evaluate the network performance based on real measurement from a developed testbed.

Moreover, in other researches, ping is used to generate stable traffic where packet size and delay between packets are constant. However, this paper introduces a customized ping tool that has the ability to generate random traffic to represent the actual environment where network traffic is no longer constant for it comes from diverse applications and communication devices in the testbed.

IV. METHODOLOGY

Smart Grid Ping is a ping utility written in C++ and is designed for Windows. It can be used to ping a single IP address or a specified range of IP addresses. The GUI provided by Smart Grid Ping is developed by using Visual Studio 2008. The flow of the program is described in the Figure 2.

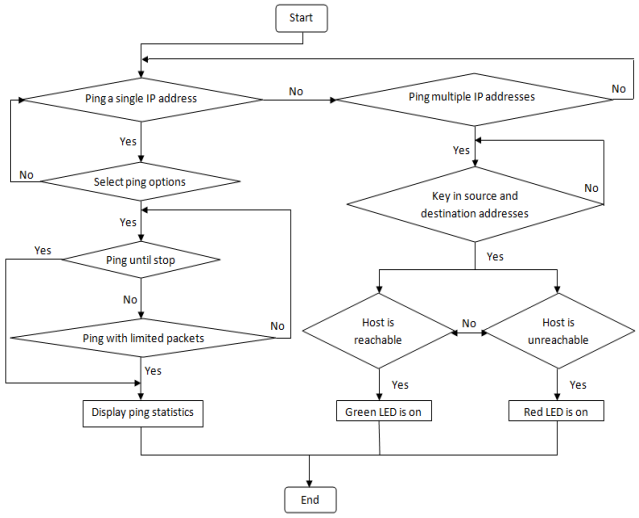

Figure 2. Flow chart.

The interface of Smart Grid Ping allows users to key in IP addresses they want to ping together with various ping options. For instance, users can select the number of packets, size of packets that they want to send, delay between packets and timeout. In addition, users can also choose to send a limited number of packets or keep on sending the packets until they want to stop.

Besides sending a constant number of packets and set a constant delay between sent packets, users can select to generate a random number. It can be Uniform, Gaussian, Poison or Exponential distribution as shown in Figure 3.

After the ping operation has been executed, the ping statistics are displayed, including the number of packets sent, received, percentage of packets lost, and round trip time. Moreover, in the window form designed for pinging multiple IP addresses, the space for source and destination hosts are provided for users to fill in. 255 LEDs, corresponding to 255 IP addresses, are used to represent the hosts' status. Green LED indicates the host is alive and reachable, whereas red LED shows that the host is unreachable.

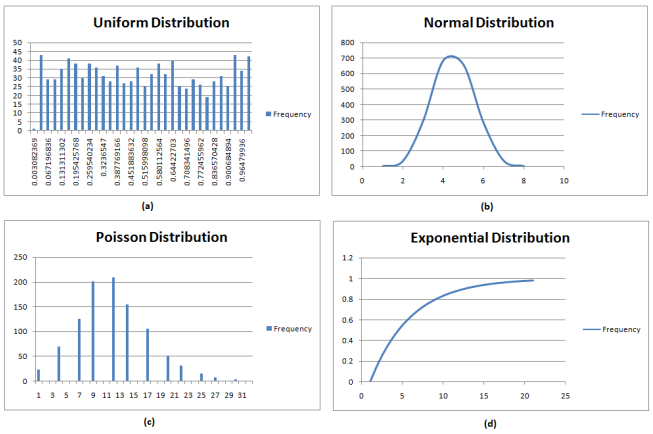

Figure 3. Types of random number distribution: (a) Uniform, (b) Gaussian, (c) Poisson, (d) Exponential.

V. RESULT AND DISCUSSION

The implemented Smart Grid Ping utility consists of three window forms. The first window is the main menu where users can choose to ping a single IP address or a range of IP addresses as shown in Figure 4. The Sing IP Ping Test form (Figure 5) provides several ping options for a single host, together with ping statistics and output display. The Multiple IP Ping Test window, as described in Figure 6, lets users key in IP addresses of source and destination hosts. It also displays all the hosts' status in rows and columns using LEDs. Initially, all the LEDs are in grey. Once the ping operation has been executed, the LED representing each host will light up accordingly.

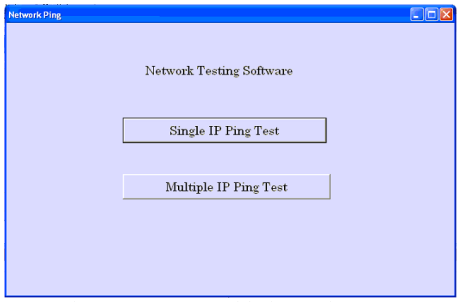

Figure 4. Smart Grid Ping main menu.

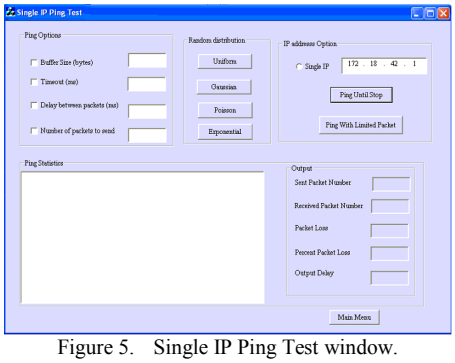

Figure 5. Single IP Ping Test window.

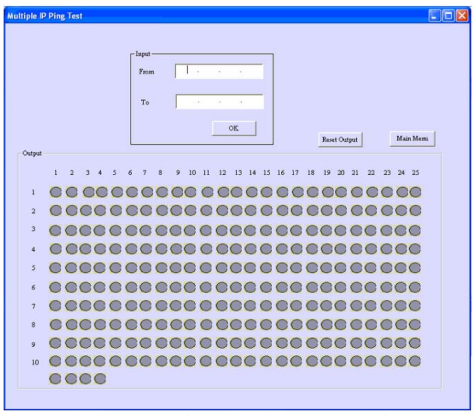

Figure 6. Multiple IP Ping Test window.

Figure 7 and Figure 8 show the user's choices and corresponding results for pinging a single IP address. The former displays the host is reachable, indicating that the device is alive. Meanwhile, the latter displays unreachable host, showing that the machine is currently unavailable or cannot be reached.

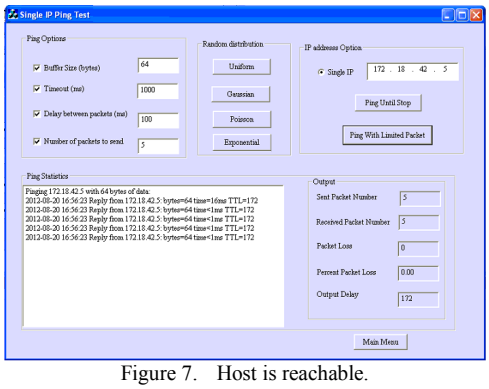

Figure 7. Host is reachable.

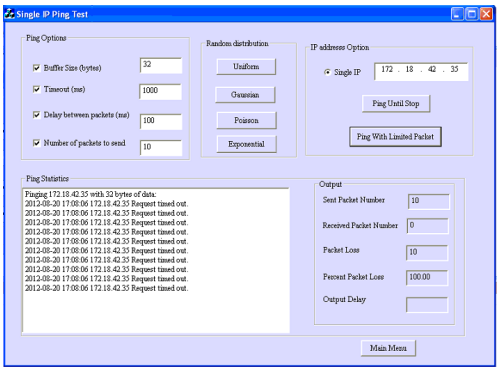

Figure 8. Host is unreachable.

The results obtained from pinging multiple IP addresses are described in Figure 9. The window provides a general view of all the devices in the network where each device is recognized by its IP address. The status of each machine is represented by green or red LEDs, indicating the host is reachable or unreachable, respectively.

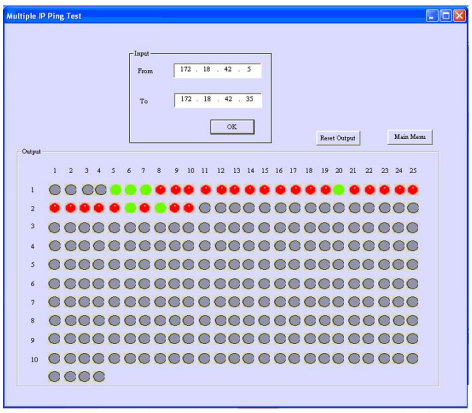

Figure 9. Multiple hosts' status with LED display.

The Multiple IP Ping Test window lets users to view the devices' status over the whole testbed area. This allows users to group certain regions with similar state, either reachable or unreachable, together. For instance, a series of continuous red LEDs from 172.18.42.8 to 172.18.42.19 indicates that the hosts corresponding to these IP addresses are currently not available. With this function, Smart Grid Ping helps system administrators detect any network problem if it arises by providing a quick view of network performance.

VI. CONCLUSION

This paper introduces a customized ping utility, called Smart Grid Ping, to test the behavior of several devices in smart grid communication network. The software was developed in such a way that users can ping a single IP address or any specific range of IP addresses. It also offers a variety of ping options and different types of random distribution to generate random number of packets and delays. These are important characteristics in evaluating the performance of smart grid communication network.

The GUI provided by Smart Grid Ping also allows users to view results of the ping operation. The availability and reachability of various smart grid applications were displayed in green and red LEDs, offering a geographical view of all the hosts' status in the network. The results obtained from this customized ping utility can also help administrators to be aware of any network problem if it occurs, identify the location where it happens and response quickly to secure the problem. As for future work, the function of Smart Grid Ping can be further improved by integration with Google Earth to provide an overview of all devices in a smart grid geographically.

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