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Smart Grid: Network simulator for smart grid test-bed

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Abstract. Smart Grid become more popular, a smaller scale of smart grid test-bed is set up at UNITEN to investigate the performance and to find out future enhancement of smart grid in Malaysia. The fundamental requirement in this project is design a network with low delay, no packet drop and with high data rate. Different type of traffic has its own characteristic and is suitable for different type of network and requirement. However no one understands the natural of traffic in smart grid. This paper presents the comparison between different types of traffic to find out the most suitable traffic for the optimal network performance.

1. Introduction

Based on the definition from U.S. Department of Energy (DOE), "A smart grid uses digital technology to modernize the electric system from large generation, through the delivery systems to electricity consumption. A strong communication system is required in order to run Smart grid application [1]. The choice of a communication architecture and infrastructure represents a major issue that needs to be addressed [2]. A number of technologies were deployed in various smart grid initiatives. This ranges from wired technologies such as ADSL to POTS (plain old-fashion telephone) carried by incumbent telephone company to WIMAX and GSM provided by broadband access service providers. If a power utility wish to operate its own infrastructure, wired technology such as PLC and short-range wireless technology such as WiFi, ZigBee, and some proprietary wireless link will be the natural selection. Choice of a technology is depended on cost, accessibility, geographic location, terrain, population and building density, etc. In most instances, hybrid of technologies will be the best solution [3,4].

In order to investigate the performance and scalability of the network, network simulation is needed. Network simulator is a software program that imitates the working of a computer network. In simulators, the computer network is modeled with applications, devices, traffic and the performance is analyzed. Users can then customize the simulator to fulfill their specific analysis needs. In this simulation, Network simulator 2 is being chosen to perform the investigation because it is an open source software and more suitable for this network topology.

The main objective in this paper is to determine the type of traffic that suitable for the designed network by using different traffic generator. Three traffic generators will be tested in this project which is Constant Bit Rate (CBR) traffic generator, Pareto traffic generator, and Exponential traffic generator. CBR traffic generator is a fundamental traffic generator which sends data in a constant rate. On/ Off Pareto traffic generator is an advance traffic generator which embedded in oTCL application. Packets are sent at a fixed rate which specified by user during on periods, and no packets are sent during off periods [5]. An exponential on/off traffic generator acts as a CBR traffic generator during an ON interval and does not generate any payload during an OFF interval. On and OFF periods are both
exponentially distributed [5]. This paper will discuss on the comparison of the result on different type of traffic. Thus, find out the suitable traffic type for the designed network.

2. Validation of Network Simulation

The main concern in this project is on getting the lowest delay and packet drop for different scenario in this designed network. This network represents smaller scale of current smart grid network with the combination of different topologies. The designed network consists of two technologies which are wired and wireless and three different types of network topology, mesh topology, star topology and point to point topology.

Figure 1. Network Design for Smart Grid Test-bed.

In the testing, nine substations which label as A to I will ping to J to check on the delay. The testing results are shown in Table 1. The result will then verify by “Student Test T”, to prove that the null hypothesis is true. The null hypothesis in this testing is that there are no different between the result for real life testing and simulation. The t-test gives the probability that the difference between the two means is caused by chance. It is customary to say that if this probability is less than 0.05, that the difference is ‘significant’, the difference is not caused by chance [6]. The probability shows the percentage of null hypothesis for being true.

Table 1. Real Time Testing versus Simulation for each link.

| Link | Average Latency (ms) |
|------|---------------------|
|      | Real time testing   | Simulation      |
| A - J| 340                 | 321.506         |
| B - J| 312                 | 307.51          |
| C - J| 300                 | 301.36          |
| D - J| 299                 | 300.812         |
| E - J| 267                 | 284.148         |
| F - J| 304                 | 303.639         |
| G - J| 326                 | 325.617         |
| H - J| 322                 | 321.112         |
| I - J| 362                 | 361.811         |
“Paired student t-test” has been performed to compare the similarity of the network simulator with the real testing. The probability of the result is 0.873, which is 87.3 percent. Therefore, it can be conclude that result for real time testing and result for simulation are coming from the same family.

3. Result on simulation- Comparison on Traffic Generator

In the simulation, traffic generator will be placed in nine substations which label as A, B, C, D, F, G, H and I in the figure 1. All the traffic generators will then generate traffic to J, control center in Figure 1. The simulation will be conducted for 20 minutes to check on the capability of the link to handle traffic during burst time. Traffic settings for the simulation is depend on the project’s background and its requirement. There are total 104 nodes in this simulation and all nodes use UDP transport protocol. The packet size and interval time defined as 1000 bytes and 0.01 second in the simulation.

In this section, we simulate the network by using different type of traffic generator and with different sending rate. About the simulation scenario, first we build the simulation network based on the project’s requirement which include wired and wireless technologies and different network topology. Nine traffic generators are place in A, B, C, D, E, F, G, H and I in Figure 1. All traffic generators will generate traffic to a control center which label as J in Figure 1. Based on the designed network we test on the performance and reliability of 3 different type of traffic generators, Constant Bit Rate, Exponential and Pareto traffic generator which available in NS2. The performance test and reliability test include testing on maximum delay and drop packet over the simulation. The total simulation time is 1200 seconds for all scenarios.

First, we compare maximum delay for three different traffic generators. Traffic generators will generate packet based on the sending rate to the control center. The sending rate that tested in the simulation varies from 1 kbit/s to 1000kbit/s. The maximum delay increases until it reaches the saturation point where the delay is about 0.85 second. In Figure 2, we compare the maximum delay among three different traffic generator with various sending rate. There is no significant different on the maximum delay for this three traffic. CBR traffic generator has a little higher delay when the sending rate is 200kbit/s. The maximum delay for CBR traffic generator varies from 0.32 second to 0.8 second when it reaches the maximum sending rate. While Pareto traffic generator and Exponential traffic generator generates a constant delay when they reach the maximum sending rate for the network. As describe from Figure 5, CBR traffic shows a slightly better result on performance compare to Pareto and Exponential traffic generator.

![Maximum delay vs Sending Rate](image)

**Figure 2.** Compare Maximum delay among Different Traffic Generators.

Second, packet drop for different traffic generator based on different sending rate is shown in Figure 6. Similarly to the first test, the packet size for each data is 1000 bytes, but the sending rate that tested in this simulation varies from 1 kbit/s to 2000kbit/s. Figure 3 shows the result on comparing the
packet drop for three traffic generators. The percentage packet drop increases until it reaches the saturation point where the sending rate is about 1200kbit/s. The higher packet drop implies the reliability for the network is lower. As observe from Figure 6, Pareto traffic generator and Exponential traffic generator are more suitable for this network because of their capability in delivering packets in acceptable packet lost range.

![Packet Drop vs Sending Rate](image)

**Figure 3.** Compare Percentage of Packet Drop among Different Traffic Generators.

4. **Conclusion**

Three different types of traffics that generate by CBR, Pareto and Exponential traffic generator have been tested in the simulation. The reliability and the performance have been analyzed for UDP transport protocol. Results achieved by the analysis for both simulations suggest that the designed network is suitable for Pareto and Exponential traffic. The designed network has a better performance on handling delay for CBR traffic, but the reliability of the network is lower. The network has the ability to handle the delay and packet drop when the Pareto traffic is saturated. Exponential traffic is also suitable for this network. The performance is only slightly lower on handling the Exponential traffic compare to Pareto traffic.

5. **References**

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