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An Ingenious Multiple Communicator Concept for Next Generation Smart Metering Communication System

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Abstract

In this article, we propose and study a self-switching network concept known as an ingenious multiple communicator mechanism which can be applied to energy provider's smart metering device. We outline reasons why such multiple connections networks are required through real case study scenarios and key components that drive towards such concept. We have gathered actual measurement values for a particular network and identified in what situation this is most suitable and applicable. We have come out with the basic system model for this multiple communicator. We also observed that a less fluctuating and similar pattern of network performance helps to design better network predictive analytics function. Finally numerical examples and analysis of the results are presented.

***Keywords**: Cognitive selection mechanism, smart meter, smart home, advanced metering infrastructure, multiple broadband.*

1. Introduction

Advanced metering infrastructure (AMI) is part of power distribution subsystem in a complex smart grid network, which is designed to be an automated architecture. This automatic architecture should consist of two-way communication between an IP based smart meter and utility company. The goal of an AMI is to provide utility companies such as energy provider with real-time data about power consumption and allow customers to make informed choices about energy usage based on the price at the time of use [1]. Real-time data transmission certainly requires reliable backhaul connection anywhere and anytime. Having a single communication network to establish and maintain connection between customer's smart meter and utility company was known to introduce risks due to communication lost, call drop-outs and out-of-coverage signaling especially on collecting real-time data in short period of interval [2].

Other than communication lost issue on relying a single network connection at the smart meter, a study report from Tenaga Nasional Berhad (TNB) of Malaysia found that [3], the migration from Global Systems for Mobile Communications (GSM) to General Packet Radio Service (GPRS) 2G technology due to better coverage and better technical support services provided by the telecommunication providers impacted almost 45,000 TNB Large Power Customers (LPC). In addition, the recent 2G spectrum re-farming strategy by Malaysian regulator [4], can eventually leads to another migration to be addressed to a significant number of customers. This is critical should the aim of TNB to

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provide more than 8.5 million customers with smart meter by 2021 comes true [5]. In view of this, it was suggested in [3] that, communication services should be multi-sourced and depending on their areas of strengths as well as reliability of continuous signals with guaranteed of handling large amount of data.

It has also been studied that, the amount of actual data that need to be updated on every 15 minutes interval from a smart meters can be as minimum as 4.55 bps [6]. Considering this small amount with actual 15-40 kbps transmission rate for GPRS [7], it is sufficient to transmit the data using just GPRS technology. However, it should be anticipated that, data can be large when smart meters are deployed in many customer residences which can eventually utilize maximum available channel capacity. If a smart meter is readily available for 3G and 4G networks, different technology shows different bit-error-rate (BER). As an example, fiber optic can results into 5E-07, 3.16E-06 for WiMAX and 7.5E-06 for 3G technologies [6].

Since the development of smart meter for AMI has already been established and deployed in some countries, it is easy to purchase such products in the market [8], [9], [10], [11]. There is also a microprocessor available for energy related hardware design [12], [13] which helps to customize one's smart meter should off-the-shelves are pretty rigid and limited with capabilities. Nevertheless, all of these products can only provide one connection at a time and there is no intelligent network switching mechanism that can self-select or self-switch a reliable and good network for maintaining the connection. It can be understood that, having multiple connectivity can incur more cost to the provider, but experiencing connection lost which requires technicians to fix the problem at reported location which perhaps need some network analysis, data tracking during the lost, updating and so on can be more daunting than having additional communication network alternative. Of course it is exaggerating to predict and have 90% communication breakdown most of the times, but it can happen in wireless transmission when there are mobile obstructions that may degrade the existing signal even further. Having discussed the above issues, Figure 1. summarizes key components of single backhaul communications challenges that drive our studies to develop an ingenious multiple communicator concept.

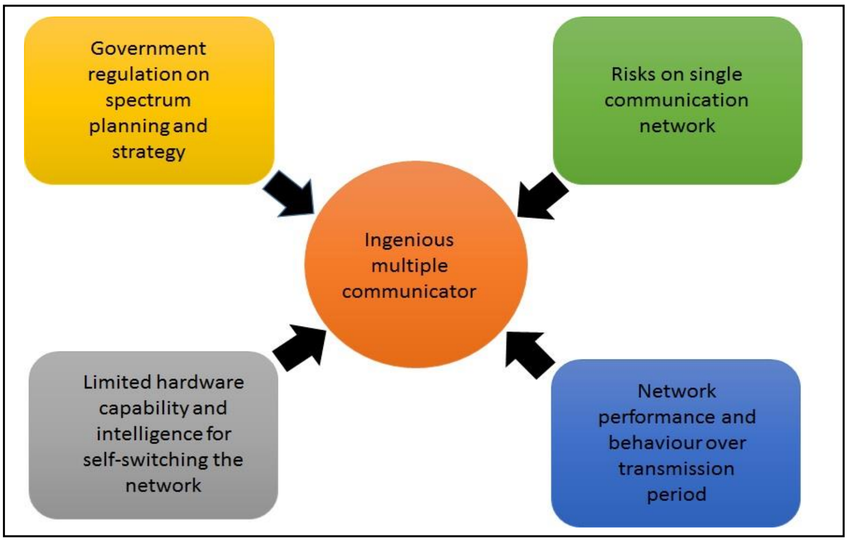

Figure 1. Key Challenges that Motivate Development of Ingenious Multiple Communicator

This paper highlights the proposed concept of ingenious multiple communicator using cognitive network selection (CNS) mechanism technique which was studied by [14], [15], [16]. For our empirical studies, we have measured performance of a subscribed network at one location in two consecutive days to analyze on its behaviour. The analysis was conducted to identify the time when network least perform based on the connection speed measurement.

The rest of the paper is organized as follows. Section 2 described in brief the ingenious multiple communicator incorporating CNS. Section 3 covers the system architecture. Section 4 discusses our experimental set-up on measuring the network behaviour. Experimental results and discussion are discussed in Section 5. Finally, concluding remarks are highlighted in Section 6.

2. Ingenious Multiple Communicator

2.1. System Block Diagram

The proposed concept of ingenious multiple communicator consists of two different components. The first component is a hardware communicator which acts as an external communication modem to the existing smart meter. The second component is the cognitive algorithm that is embedded into the communicator unit and the combination becomes a module that can be sold on its own. As an illustration, Figure 2 and Figure 3 show system block diagram for a single backhaul communication smart meter and the newly proposed multiple connection smart meter, respectively.

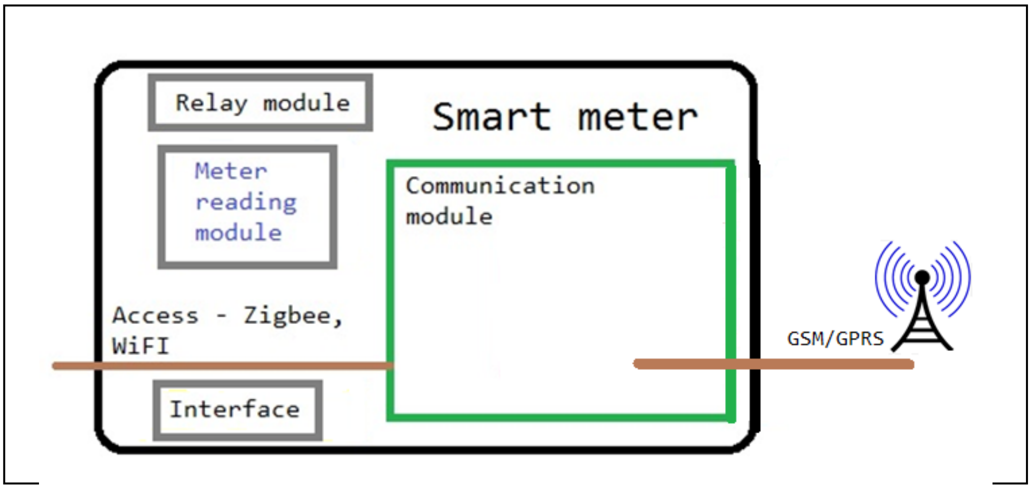

Figure 2. Single Backhaul Network Connection Smart Meter

2.2. Cognitive Network Selection

The crucial hypothesis in cognitive radio (CR) involving three key ideas in particular detecting, examining and decision are connected as the central system in Cognitive Network (CNS) [13]. The procedure of detecting and starting changes inside the radio framework while giving steady system association are among the strategies created in cognitive or intellectual. Another part of cognitive sciences conveyed is the Artificial Intelligence (AI) to astutely pick and choose for best network determination. This is achievable by executing such segments in an ingenious algorithm that fit for controlling the system determination at the physical layer of a specialized gadget. Having depicted the hypothetical components of CNS, this idea upgrades such essential insight by consolidating a few subscribed broadband service choices with new determination parameter and system as appeared by Figure 4. These broadband services could comprise of General Packet

Radio Service (GPRS), Long Term Evolution (LTE) and worldwide interoperability for microwave access (WiMAX).

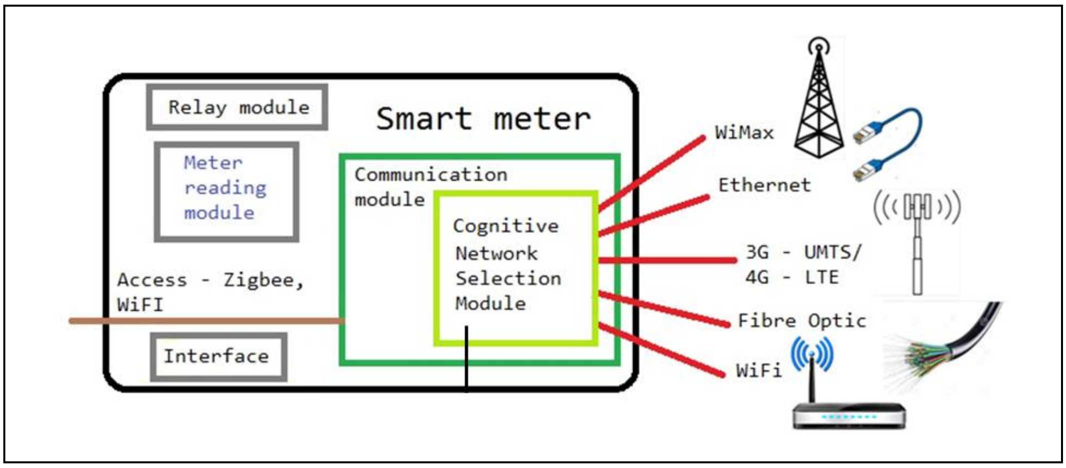

Figure 3. Proposed Multiple Backhaul Network Connection Smart Meter with Self-Switching Capability

One of the models introduced in CNS [15] is the successive selection model. Advanced determination ready to accomplish the checking, assessing and sorting procedure for the resulting the best accessible registered wireless connections inside indicated interim timeframe. It is through filtering and assessing progression that controls the conduct of the system in its cutting-edge decision constructing. Figure 5 demonstrates the flow chart of successive choice. It starts through random association with any pledged network. Once associated, the network determination will begin through downloading a predefined record estimate that would show the connection speed. So, at that moment captured and saves inside a provisional database. It is then detaches with the main network and repeats the same procedure with whatever remains of the networks. The connection speeds that had been captured in the database are then positioned in the plummeting request. The system determination component will choose and connection with the network with the most elevated connection speed. This procedure will be repeated for an interim timeframe. The time interim is built up contingent upon the rate of association rate vacillation. The change could fluctuate taking into account a few elements, for example, the condition of the terminal whether mobile or stationary, wireless interferences *e.g.* broadband signal interfered with another signal of same frequency, traffic congestion and so forth. In this research, 1800s was determined as the interim of time for the project to rehashes its assessment as well as determination of the best availability procedure. As a result of this repeated examining procedure inside the predefined time interim, this determination instrument endures moderate system exchanging delay. Such exchanging deferral may bring about badly designed system intrusion to the clients. To apply to this smart meter system, the interval time to evaluate network connection can be triggered when there is delay of receiving real-time data out of specified window frame time. In this case, checking the network behaviour can be reduced and only conducted when necessary.

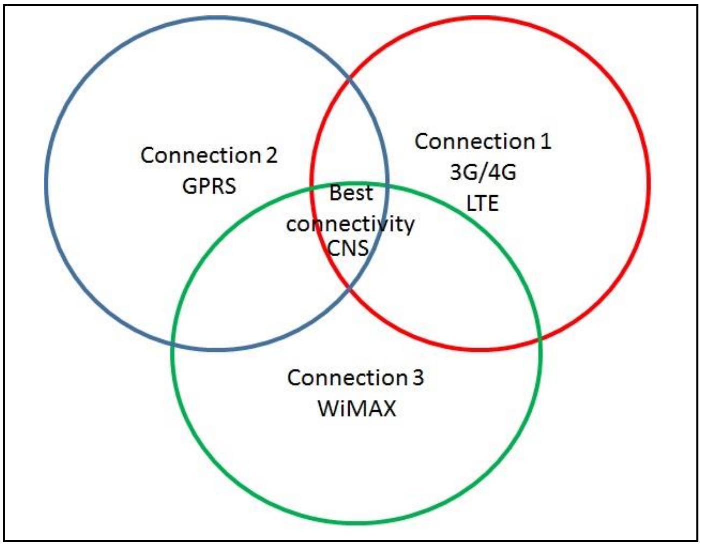

Figure 4. Cognitive Network Selection Concept

3. System Architecture

The system architecture for our ingenious multiple communicator is illustrated in Figure 6 as applied within AMI topology framework. From the diagram, our proposed modular concept be incorporated not only at the smart meter but also at the data collector unit (DCU) as well as data aggregator unit (DAU). In general, any devices that require backhaul connection, our module can be help to integrate without the need to change to a new system.

4. Experimental Setup

Figure 7 shows the laboratory empirical studies for analysis of the network performance. In order to emulate such multiple communicator module, a subscribed network was connected to the computer and web application such as speedtest.com was used to capture the connection speed of the mobile broadband. In this experiment we have subscribed 3G broadband service by Maxis. Two locations were identified for measuring the network speed. Only one mobile broadband was subscribed during this experiment due to better quality of service within campus area as well as residential area. However for this paper we will only analyze network performance for campus area and discuss these two location comparison in the next paper.

Table 1 describes the system parameters used in this experiment. Since this is a preliminary monitoring, network performance was captured based on download speed of the network using a fix file size which is 2Mbits at a specific location. The successive algorithm was not yet applied since the target of this analysis is just to learn and understand the network behaviour for specific period of time that is from 8:00 in the morning till 12:00 midnight.

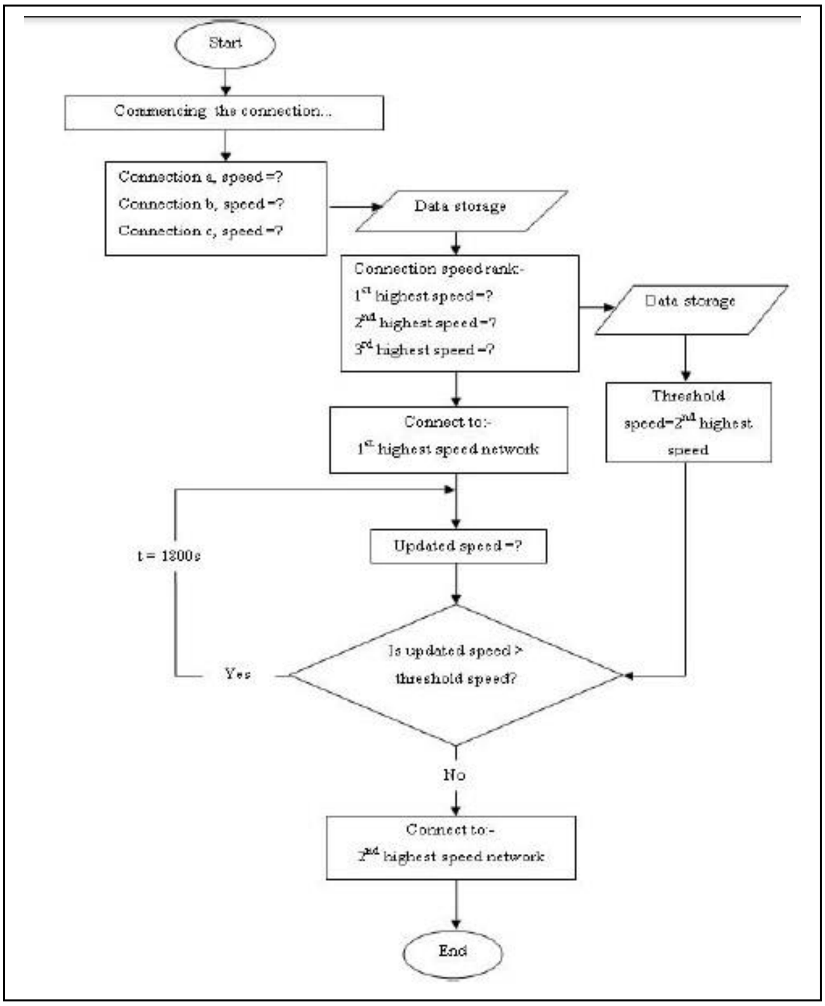

Figure 5. Cognitive Network Selection Flowchart using Successive Selection Technique

Table 1. System Parameters

Parameter	Description
Frequency band	3G broadband at 2.1GHz
Operating system	Window OS
Data monitoring time	8am – 12am
File size for testing	2 Mbits
Location	Universiti Tenaga Nasional campus
Subscribed nextwork	Maxis broadband
Measurement interval	30 minutes = 1800s

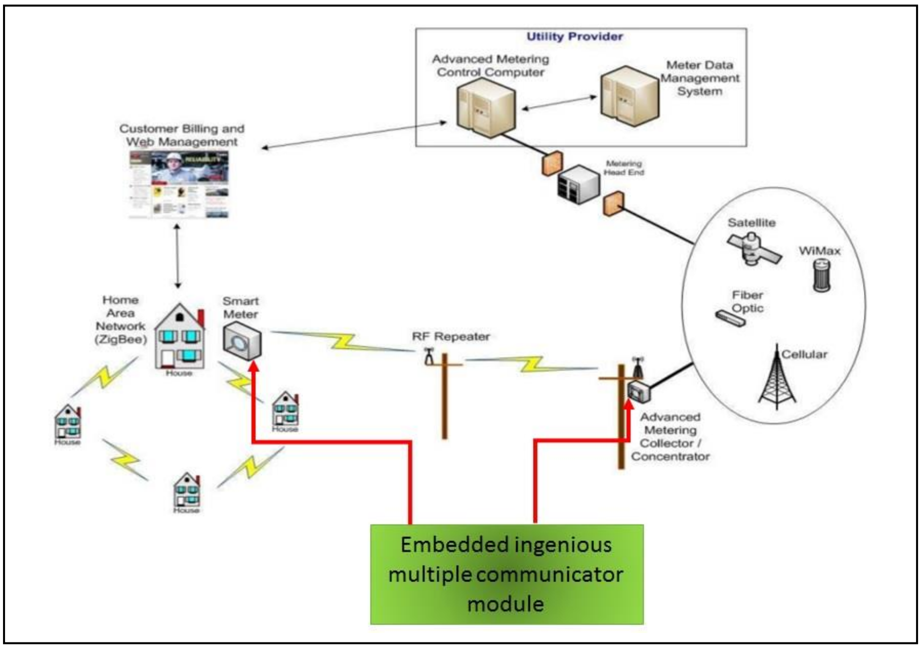

Figure 6. AMI Topology Reproduced from [17] with Application of Ingenious Multiple Communicator Module

7. Results and Discussions

The results from this experiment are depicted in Figure 8 and 9. Figure 8 shows the network performance based on download connection speed when monitored from 8am till 5pm for two consecutive days. The mobile broadband is based on single subscription of a similar network. From the result we can observe that during day 1, the performance quite fluctuate from 8am till at least 11am within the lowest range of 0.5 Mbps to the maximum range of 5 Mbps. This implies that obtaining real-time data from the smart meter that depends on this 3G broadband network can be experiencing some packet loss and delays since the quality of the network can influence the transmission rate of the data. Beyond 11am the network performance starts to degrade and slowly fluctuate between 0.2 Mbps – 2 Mbps. The difference is only 1.8 Mbps as compares to the preceding reading with 4.5 Mbps difference. The impact on low connection speed which can results into low transmission rate is the possibility of packet loss and delays that require retransmissions. This is even worst when thousands of smart meter simultaneously sending data which might contributes to network congestion.

For day 2 connection speed monitoring, it can be observed that the range of fluctuation can be as low as 0.05 Mbps and as high as 3 Mbps. The difference of 2.95 Mbps is smaller compares to day two but the minimum value of 0.05 Mbps might cause problem to real-time data transmission. This is the situation whereby self-selecting or self-switching to a better network will be required should we have more than single options of connected network. Since it is possible to last nearly 30 minutes of duration in that minimum value, it is quite significant impact to the data transmission especially on scheduled updates at the utility companies.

Figure. 9 on the other hands, evaluates on the subscribe network performance during the evening until midnight. We can see that the fluctuation of the network performance is slower despite it is expected that more subscribers will be using internet in the evening. However, for both days we can see the network performance trend is almost similar so it is quite easy to predict when both shows almost similar performance. This input can helps our CNS to self-trigger the switching mechanism whenever network is predicted to be at lowest threshold value which occur at 21:30.

Our preliminary results certainly helps us to understand the network behaviour so that the mechanism of CNS is tailored to more realistic and actaul situation rather than relying on estimation and assumption. This is important so that our predictive analytics algorithm can reached 90 % of accuracy.

Figure 7. Experimental Setup for Monitoring Broadband Network Performance

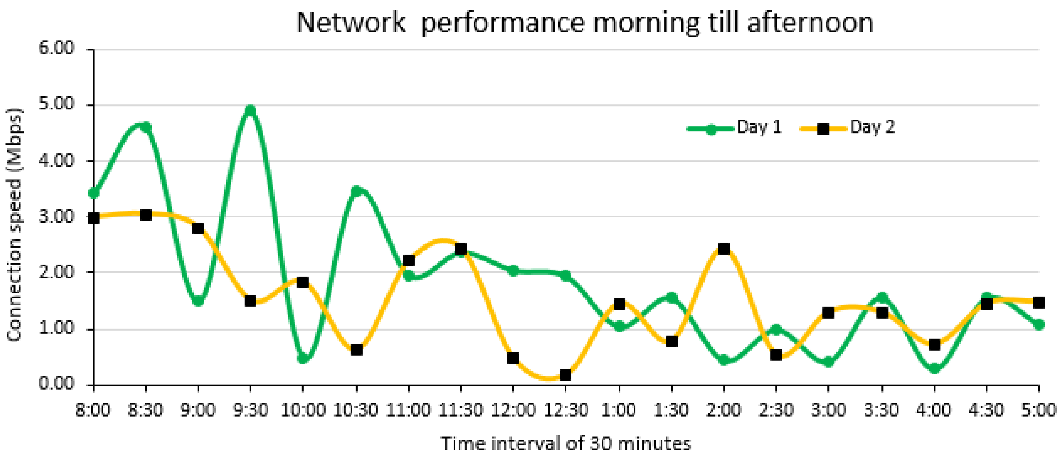

Figure 8. Network Performance Behaviour from 8am – 5pm for 2 Days

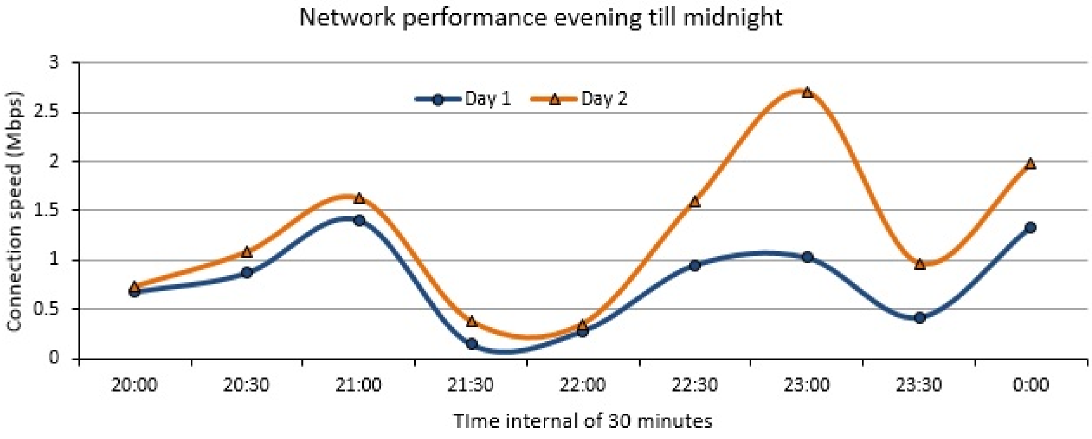

Figure 9. Network Performance Behaviour from 8pm – 12am for 2 days

8. Conclusion

Our proposed ingenious multiple communicator concept incorporates CNS to self-switch into more reliable communication network in order to ensure always-on connection. This is vital and critical in transmitting real-time data especially in AMI system for utility companies. The adapted CNS is supported by understanding and learning the behaviour of the network based on historical data at a specific location. By learning the behaviour of the network performance, triggering mechanism for self-switching to the best network can be predicted with better accuracy. As an example, for our empirical studies we learn that network performance gives fluctuating results with observed range of connection speed of 4.5 Mbps difference on half of the day and 2.95 Mbps difference the next half. During the evening time we found that the fluctuation gives almost similar pattern within two consecutive days of speed monitoring. Such similar pattern can assist us to design the triggering self-switching mechanism in order for the device to change into more reliable network. There are more works to be done in these studies and this will be reported in our next paper.

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