Performance Metrics Evaluations for Selected Proactive Routing Protocols in Smart Grid Neighbourhood Area Wireless Mesh Network

Enock Anderson

Brno University of Technology, Czech Republic

E-mail: enock.anderson@vut.cz

Abstract—The smart grid communication network has improved energy optimization delivery from generation, transmission, and consumption. The introduction of wireless mesh networks in the area of Neighbourhood ad hoc Networks has contributed to the quick and cost-effective way of deployment in the areas where back-haul technology like fiber optic is expensive and challenging and may not be timely. The IEEE 802.11s standard-based wireless mesh network associated with the hybrid wireless mesh protocol is highly recommended due to its extended functionality. However, the hybrid wireless mesh protocol based mesh networks can not guarantee the quality of service in such an environment. The OLSR (Optimised Link State Routing) protocol outperforms the Reactive protocol in ad hoc Networks when transmission quality is required. This paper proposes the adaptation of Extended Transmission Control with OLSR as the optimized protocol for such an environment in neighbourhood ad hoc networks. The simulation study was carried out using the NS3 simulator to evaluate the performance of OLSR and OLSR-ETX (OLSR with Expected Transmission Count). The results confirm the viability of this protocol for neighbourhood ad hoc networks and also outperform similar simulation using NS2. The implementation of OLSR-ETX in the neighbourhood ad hoc networks rural environment will increase reliability and improve Demand Response DR in Smart Grid.

Keywords—Demand Response, Extended Transmission Count, NANET, neighbourhood Adhoc Network, Network simulation, NS3, OLSR-ETX, Wireless Mesh Networks

1. INTRODUCTION

Smart Grid (SG) technology has contributed a lot to the 21st Century power generation. It has successfully enhanced the capabilities of the traditional energy sector to ensure advanced and automated energy delivery for the economic, and industrial growth of nations [1]. The infrastructure key elements, such as smart meters, circuit breakers, transformers, feeders, substations, control centers, grid stations are all equipped with SGCN (Smart Grid Communication Network) technology architectures and software applications to provide feedback and for monitoring of the grids in real-time for utility management and DP (Demand Response). The SGCN architecture uses a multi-layer approach of dividing the communication layer into HAN (Home Area Network), NAN (Neighborhood Area Network), and WAN (Wide Area Network) [2, 3]. The NAN is a critical layer deployed to cover the distribution and the transmission domain using communication technology like wireless, wired, optical, or a combination of two or more of these technologies are deployed to ensure reliability and high throughput in the network. Its primary function is to move a large bi-directional volume of diverse data and control information between the service providers in WAN and the HAN smart devices. NAN architecture also provides a platform for the DMR (Demand Response Management) systems of the SG. However, deploying HAN in a rural and challenging environment cost-effectively and quickly is always a challenge for utility companies. Concerning the above, WMN (Wireless Mesh Network) deployment has been researched extensively in [3, 4, 5], and developed to guarantee connectivity by building a multi-hop wireless backbone to support the fast, liable, and cost-effective means to deploy NAN, especially in the remote and rural areas where access to Back-haul technology like fiber optic cable lines will be expensive and challenging to deploy within a short period. The WMN architecture uses MAC, PHY, and routing protocols to move packets among devices.

2. STATE OF THE ART

2.1. Related Works

Related research in WMN routing protocols and routing metrics deployed in NAN, MANET (Mobile Ad hoc NETwork), WSN (Wireless Sensor Networks), and VANET (Vehicular ad hoc network) are used to update and maintain the network topology in the devices [3]. The Wireless Meshed Network uses numerous sets of protocols which are proactive, reactive, and hybrid and their goal is to optimize the network performances. They all give different results regarding throughput, latency, packet loss probability, end to end delay, network gain just to mention a few. Many research works have been done on routing protocols for WMN, MANET, VANET in [3]. In [3, 4], the goal of the authors was to analyze the performance metrics of MANET and WSN using reactive protocols such as AODV (Ad hoc On-Demand Distance Vector) and DSR (Dynamic Source Routing). The authors of [5] performed a testbed experiment of protocols HWMN (Hybrid Wireless Mesh Network). In the area of proactive protocols, authors in [4] performed an analysis of proactive OLSR and OLSR-ETX on a simulation environment but the simulation used was an old version. Other ad-hoc experiments were limited to identifying MAC (Medium Access Control) problems, by providing insights on the one-hop MAC dynamics. In [6], the authors present an experimental comparison of OLSR using the standard Hop-Count and the ETX (Extended Transmission Count) metric in an 8 by 8 grid of closely spaced Wi-Fi (Wireless Fidelity) nodes with high mobility in MANET to obtain some results. This work is more close to this research which gives us a benchmark for our results. The choice of OLSR which is a link-state proactive routing protocol that performs reliably is researched in [7] for rural and agricultural environments. This paper aims to analyze the performance metrics of proactive OLSR and OLSR-ETX in a simulation environment to confirm their suitability for deployment in a rural NAN architecture. Also to compare if it is consistent with previous research using a similar simulation tool; NS2. The simulation environment is tweaked using a few network characteristics that match dispersed, heavy interference rural environments where the NANET is deployed.

2.2. Simulation Description

Simulation is a good software platform and methodology to experiment with and evaluate different network topologies scenarios without or before real-world implementation. It can be used to have a fair idea of a real-life experience of how a system will perform over a longer period as well as reduce its associated cost of live implementation [4]. Most of the available simulators, such as Omnet++, Glomosim, and NS2, are realized as dual-language simulators. One language form of simulators usually C++ or Python, used for modeling provide a better learning curve and quick implementation of the experiment. The paper [8] named NS3 as a single language simulator, written in C++, which makes it a good platform choice for this experiment. Similarly, the simulator also has some preprogrammed proactive and reactive protocol classes, other MAC/PHY parameters, and wireless standards are also preconfigured to facilitate the timely results of the experiment. The addition of ETX metric algorithms was reconfigured and also implemented on methods from [3, 9, 10]. The experimental parameters are shown in Table I.

3. EXPERIMENTAL RESULTS

3.1. Performance Measurement and Analysis

The simulation was done to match the hash agricultural environment of 500–1500 square meters. The OLSR routing and the OLSR-ETX simulations were done and the results were compared in Table II. Sample codes of the ETX routing metric for AODV from GitHub were adopted and reconfigured for the OLSR protocol routing table in NS3 and it was also compared to previous works using NS2 in [11]. Each simulation was run for 120s for both protocols. Data traffic was generated from node S to node D, and simulation results (throughput, delay, and packet loss ratio) were obtained using the FlowMonitor. Also, another simulation was performed to select a route based on the ETX metric. The initial ON seconds were meant for sending ETX probe packets to the destination node, the second Off timer handled the

Table I: Experimental parameters

Protocol	OLSR/ETX
Number of Nodes	10
Logical Link	mesh
MAC	IEEE 802.11g
Flow Type	CBR
Bandwidth	2 Mbps
Packet Size	1024 bytes
Number of Trials	20
Duration	120 sec
Propagation Method	Friis Loss Model

probe. On receiving an ETX probe packet the forward delivery ratio and reverse delivery ratio of a link was calculated to find the value of ETX. The routes chosen for routing the packets consider the ETX value while updating the routing table with the obtained link quality. The process guaranteed the ETX values of its constituent links. In all the simulations performed, the preconfigured ETX for OLSR was able to identify the links with less hops and with better reliability. In the case of the OLSR protocol, it consistently chose the shorter path regardless of the poor link speed. Because of this, the OLSR-ETX outperformed the previous protocol. The performance of the simulation was calculated and measured based on the metrics listed below:

1. Packet Delivery ratio (PDR)

$$Deliveryratio = \frac{TotalPacketreceived}{TotalPacketsent} \cdot 100\ [\%] \tag{1}$$

2. Average Throughput

$$Throughput = \frac{D}{T}\ [kbps] \tag{2}$$

3. Packet Delay (source node (sent at Pds) to the destination node (received at Pdr))

$$Delay = Pdr - Pds\ [s] \tag{3}$$

4. Expected Transmission Count (ETX), proposed by De Couto et al, is a prediction routing metric of a link.

$$ETX = \frac{1}{pf \cdot pr} \tag{4}$$

Table I the parameters for the simulation that depicts a rural NANET deployment by other APs disseminated within the campus. In general, the interference from other APs is non-controllable.

Table II: Simulation results

Protocol	**Data Load [Kbps]**	**Hop Count /EXT**	**Average Throughput [Kbps]**	**Packet Delivery Ratio [%]**	**End to End Delay [ms]**
OLSR-EXT	10	8/11	8.72	87.21	34.23
OLSR	10	8/- -	7.84	78.42	36.77

OLSR-EXT	20	8/11	19.65	98.26	23.12
OLSR	20	8/- -	16.94	84.70	35.54
OLSR-EXT	30	8/11	29.66	98.87	21.53
OLSR	30	8/- -	26.54	88.45	33.87
OLSR-EXT	40	8/11	39.69	99.23	21.20
OLSR	40	8/- -	37.65	94.13	32.67
OLSR-EXT	50	8/11	49.93	99.87	19.68
OLSR	50	8/- -	47.38	94.77	29.88

3.2. Discussion

To assess the viability of proactive standard OLSR and OSLR ETX protocols for use in rural HANET environments, was the focus of this simulation. With that said, both routing protocol's simulation outputs were compared using tools like NetFlow, Wireshark, and trace metrics. The multi-route and hop were captured and analyzed and the ETX metrics performance was captured and analyzed according to the performance of various metrics calculations stated above. The results in Table II show that the initial bandwidth and resources were being utilized by the protocol to establish acquaintance of the network nodes and also it was using both multicast and broadcast messages which caused higher delays and low throughput. However, after the links and structure of the network had been established in various routing tables, the output was very much improved. Again it was observed that the ETX outperformed the standard OLSR in terms of End to End delay, Packet Delivery Ratio, and throughput.

4. CONCLUSION

This paper used the NS3 simulation tool to design a network topology of ten nodes with IEEE 802.11g devices with multipath and channel capabilities. The simulation has reconfigured the standard OLSR protocol to adapt the ETX metric in multipath/hop decisions that match the deployment of HANET. We compared the performance of the proactive OLSR routing protocol with Hop-Count and OLSR protocol implementation with the widely used ETX metric in the NS3 simulator. As expected, OLSR-ETX performed better than Hop-Count OLSR in terms of the Average Throughput and Packet Delivery Ratio and performed similarly in End to End Delays. Since the simulation has shown results consistent with related testbeds and simulations, it can be concluded that the implementation of the ETX metric in the NS3 simulator was successful and can guarantee reliable results when used in HANET for SGCN. However, in the simulation parameters, it was assumed that the energy source for the wireless nodes was reliable, but in the simulations, it was observed that the OLSR protocol draws much power from the nodes and also does not consider the energy state of the route when forwarding packets. This may lead to loss of links or reliability challenges in areas where nodes experience power losses. In this regard, there is a need to research further the energy management of proactive protocols in areas where there will be energy challenges for the wireless node devices. Future research should consider energy in the assessment of neighboring links when updating the route before forwarding packets.

REFERENCES

[1] W. Meng, R. Ma, and H.-H. Chen, "Smart grid neighborhood area networks," *IEEE Network*, vol. 28, no. 1, pp. 24–32, 2014. [Online]. Available: http://ieeexplore.ieee.org/document/6724103/

[2] N. Raza, M. Q. Akbar, A. A. Soofi, and S. Akbar, "Study of smart grid communication network architectures and technologies," *Journal of Computer and Communications*, vol. 07, no. 03, pp. 19–29, 2019. [Online]. Available: http://www.scirp.org/journal/doi.aspx?DOI=10.4236/jcc.2019.73003

[3] N. J. Jevtic and M. Z. Malnar, "The ns-3 simulator implementation of etx metric within aodv protocol," *2017 25th Telecommunication Forum (TELFOR)*, pp. 1–4, 2017. [Online]. Available: http://ieeexplore.ieee.org/document/8249315/

[4] T. Wollenberg, “Performance measurement study in a wireless olsr-etx mesh network,” *2012 IFIP Wireless Days*, pp. 1–7, 2012. [Online]. Available: http://ieeexplore.ieee.org/document/6402882/

[5] J. Dusek and J. Mikulka, “Measurement-based domain parameter optimization in electrical impedance tomography imaging,” *Sensors*, vol. 21, no. 7, 2021. [Online]. Available: https://www.mdpi.com/1424-8220/21/7/2507

[6] A. Abu Salem and H. Awwad, “Mobile ad-hoc network simulators, a survey and comparisons,” 06 2014.

[7] S. Lalar and A. Yadav, “Comparative study of routing protocols in manet,” *Oriental journal of computer science and technology*, vol. 10, no. 1, pp. 174–179, 2017-03-28. [Online]. Available: http://www.computerscijournal.org/vol10no1/comparative-study-of-routing-protocols-in-manet/

[8] S. Alam, M. F. Sohail, S. A. Ghauri, I. Qureshi, and N. Aqdas, “Cognitive radio based smart grid communication network,” *Renewable and Sustainable Energy Reviews*, vol. 72, pp. 535–548, 2017. [Online]. Available: https://linkinghub.elsevier.com/retrieve/pii/S1364032117300977

[9] A. Zakrzewska, L. Koszalka, I. Pozniak-Koszalka, and A. Kasprzak, “Analysis of routing protocol performance in wireless mesh networks,” *2010 International Conference on Computational Science and Its Applications*, pp. 307–310, 2010. [Online]. Available: http://ieeexplore.ieee.org/document/5476663/

[10] M. Malnar and N. Jevtić, “A framework for performance evaluation of vanets using ns-3 simulator,” vol. 32, no. 2, pp. 255–268, 2020-03-15. [Online]. Available: https://traffic.fpz.hr/index.php/PROMTT/article/view/3227

[11] M. Hiyama, E. Kulla, M. Ikeda, L. Barolli, and M. Takizawa, “Performance comparison of olsr with etx_float and etx_ff in a manet testbed,” *2013 Seventh International Conference on Complex, Intelligent, and Software Intensive Systems*, pp. 8–14, 2013. [Online]. Available: http://ieeexplore.ieee.org/document/6603859/