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Performance Evaluation of Communication Infrastructure for Peer-to-Peer Energy Trading in Community Microgrids

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Abstract: With the rapidly growing energy consumption and the rising number of prosumers, next-generation energy management systems are facing significant impacts by peer-to-peer (P2P) energy trading, which will enable prosumers to sell and purchase energy locally. Until now, the large-scale deployment of P2P energy trading has still posed many technical challenges for both physical and virtual layers. Although the communication infrastructure represents the cornerstone to enabling real-time monitoring and control, less attention has been given to the performance of different communication technologies to support P2P implementations. This work investigates the scalability and performance of the communication infrastructure that supports P2P energy trading on a community microgrid. Five levels make up the developed P2P architecture: the power grid, communication network, cloud management, blockchain, and application. Based on the IEC 61850 standard, we developed a communication network model for a smart consumer that comprised renewable energy sources and energy storage devices. Two different scenarios were investigated: a home area network for a smart prosumer and a neighborhood area network for a community-based P2P architecture. Through simulations, the suggested network models were assessed for their channel bandwidth and end-to-end latency utilizing different communication technologies.

Keywords: communication infrastructure; P2P energy trading; smart prosumer; microgrid

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1. Introduction

Traditional power systems were developed decades ago based on centralized architectures, in which electricity is generated from central electric power plants, transmitted to the substation via transmission power lines, and then distributed to the consumers. In order to lower greenhouse gas emissions and boost energy efficiency, all nations are now creating new rules and regulations to encourage the integration of renewable energy sources. In Saudi Arabia, the plan of Saudi Vision 2030 for energy transition and sustainability aims to reach 50% renewable energy using solar and wind power in the overall energy mix by 2030 and Net Zero by 2060 [1]. In this direction, in the residential sector, Saudi Arabia's electricity and cogeneration regularity authority introduced in the August 2017 regulations allows households to generate their own electricity using solar energy [2]. As a result, in 2018, the number of installed solar panels increased in the majority of regions, especially in the Riyadh region. Since then, a significant number of customers have participated in connecting their generation systems with electric utilities, especially photovoltaic energy systems. More customers are predicted to participate in the use of the smart grid via demand-side management incorporation in the power system [3–6].

Peer-to-peer (P2P) energy trading is set to play an important role in direct energy sharing among prosumers in the future smart grid; however, issues relating to large-scale implementation still need to be addressed in order to enable reliable and secure

operation [7]. In P2P energy trading, instead of relying on the main power grid, prosumers ate able to sell/buy from each other. However, such implementation of P2P energy trading poses many technical challenges in relation to electric power constraints, communication network requirements, and security and privacy issues [8].

In order to support the development of a future smart grid, there are different organizations and standardizations which have been working to define smart grid requirements and architectures from various aspects such as grid management, communication, networking, and security and privacy. Among the international organizations and standardizations are the International Electrotechnical Commission (IEC), the IEEE Standard Association, Internet Engineering Task Force (IETF), and International Telecommunication Union-Telecommunication (ITU-T) standardization sector [9]. Examples of widely accepted smart grid standards are the national institute of Standards and Technology (NIST), the IEEE 2030 standard, and the smart grid architecture model (SGAM). The SGAM architecture consists of five interoperability dimensions (component, communication, information, function, and business), five domains (generation, transmission, distribution, DER, and customer), and five zones (process, field station, operation, enterprise, and market) [10].

With the increased growth of distributed energy systems such as solar photovoltaic, battery storage systems, and electric vehicles, P2P energy trading has emerged as the next-generation form of energy management that is set to play an important role in enabling local energy trading for selling/buying among prosumers in the residential power grid. Such P2P energy trading could bring many benefits to all participants, including consumers, prosumers, and service providers. In such implementations, communication infrastructure will play an important role in enabling all market participants to communicate with one another in P2P energy trading. However, different communication architectures could be considered to support information exchange. Such architectures include, in general, centralized architecture, decentralized architecture, and hybrid-based architecture. The selection among different architectures should consider the performance requirements that need to be fulfilled, e.g., latency, throughput, and security. Another important aspect is the energy management system (EMS) that can enable the prosumer to have access to real-time demand and supply information, as this EMS influences the role of prosumers in deciding their participation as seller or buyer [11].

Communication infrastructure is the first step toward establishing reliable P2P energy trading among prosumers and consumers in microgrids. Such communication infrastructure would aim to enable reliable data delivery among different entities [12,13]. Most of the research in P2P energy trading has been focused on market operations, pricing mechanisms, blockchain technologies, and smart contracts, while less attention has been given to the performance of communication technologies to support P2P implementations. With a large number of participants, issues relating to communication and computation complexities must be addressed for robust and secure operations. To the best of our knowledge, there is no detailed communication network model for P2P energy trading in a community microgrid. To address this knowledge gap, this work investigated the performance of the communication infrastructure that supports P2P energy trading among smart prosumers in a community microgrid. The main contributions were:

- To develop a system architecture for local P2P energy trading which consists of five layers: power grid, communication network, cloud management, blockchain, and application.
- To develop a communication network model based on the IEC 61850 standard for smart prosumers integrated with renewable energy resources and energy storage systems.
- Evaluate the performance of HAN for a smart prosumer and NAN for a community-based P2P architecture using the OPNET modeler.
- Provide the performance analysis of different communication technologies with respect to bandwidth and end-to-end delay.

The rest of this paper is organized as follows: Section 2 presents the related work, while Section 3 presents the system architecture for P2P energy trading. Section 4 provides

a detailed network model for smart prosumers in a community microgrid based on the IEC 61850 standard. The performance evaluation and simulation results are presented in Section 5. Section 6 illustrates the conclusion and future work.

2. Related Work

Many related works have discussed the main features and benefits of P2P energy trading from different aspects for consumers, prosumers, and distribution system operators in both physical and virtual layers [4–8,11–15]. For example, the survey for the socio–technical interaction and P2P energy trading mechanism was given by the authors in Ref. [7]. This work covered information and communication technology (ICT) for energy trading interactions, the energy services of multi-scale P2P energy trading, and the operational framework for the P2P marketplace. In Refs. [4–6], the authors provided a thorough examination of existing research and implementation initiatives for hybrid renewable energy systems and future research, while in Ref. [11], the authors examined the current state of P2P energy trading strategies, features, energy markets, and the benefits for both consumers and the grid. Furthermore, this work identified the research challenges in virtual and physical layers as well as the future research directions. Ref. [14] outlined the functions of blockchain and microgrids to enable peer-to-peer energy trading, while Ref. [15] offered an assessment of the literature on P2P kilowatts and megawatts in the distribution of power systems.

In [16], the authors developed P2P energy trading for microgrids using blockchain and the Internet of Things (IoT) technologies. This work provided basic information for the technical implementation of the P2P energy trading setup, including hardware (current sensor, Arduino board, LED, power supply, relay, and light bulbs) and software (Node-Red). The work considered a basic scenario between two peers only for the P2P energy trading model. In [17], the authors presented low-cost, open-source P2P energy trading for a remote community in Pakistan based on IoT and blockchain technologies. This system was designed and implemented based on six main components: field devices, ESP32, a relay, a user interface, a local WiFi network, and Ethereum private blockchain. In [18], the authors presented a review of P2P energy trading with respect to concepts, approaches, and control architectures in microgrids for local communities. This work provided a case study of the energy system in Nepal, highlighting constraints, challenges, and opportunities.

In [19], the authors designed a P2P energy trading method for optimal operation and cost-sharing when building microgrids based on a data envelopment analysis. Three cases were considered: Case 1 with all buildings holding prosumers (suitable to install PV modules), Case 2 with some buildings not suitable to install PV modules, and Case 3 with shared PV and energy storage systems. In [20], the authors presented centralized P2P energy trading for residential smart communities. A smart community with ten prosumers, an energy community manager, and an energy retailer was taken into account in the simulation scenario. Each prosumer had a solar PV and battery storage system. In [21], the authors presented the basic concept of a P2P energy trading platform using IoT and blockchain technologies. This work considered only two peers where the platform provided information that was related to metering, energy transfer, and money transfer.

In [22], the authors investigated the participation of sustainable users in P2P energy trading through social cooperation among prosumers. The feasibility of cost savings using a Canonical Coalition Game was investigated for five prosumers. In [23], the authors presented a P2P energy trading platform using the Internet of Things, Ethereum private blockchain, and a user interface based on Angular for remote communities. In [24], the authors proposed a P2P energy trading based on distributed ledger technology (DLT) for the Internet of Things application (IOTA) which provided low cost, low transaction time, and high scalability. In [25], the author introduced the 1 + 5 architectural view model for the design of cooperating IT systems for common business processes. Three case studies were given for the design of various solutions, including the electronic circulation

of prescriptions, the communication between separate IT systems, and the design of a blockchain-based solution for renewable energy management.

Security and privacy are important factors to be considered in order to suit the requirements of different applications against any physical or cyberattacks in smart grids and microgrids. Cyberattacks can target the device level (sensors and measurement devices) as well as the communication network level. Physical tampering may include damage to physical devices such as smart meters, while manipulating control signals for circuit breakers or relays may result in the disruption of the power supply. Therefore, the main indicators to be considered include availability, integrity, and confidentiality. For peer-to-peer energy trading, cyberattacks with false data injection (FDI) for renewable energy, demand, and offered prices could affect energy costs to achieve financial gain, while a denial of service (DoS) could disable the availability of information such as available resources and prices. To mitigate such problems, authentication and access control are essential at the device level. For data transmission between the end devices and control systems, digital signature and encryption were essential elements to ensure data integrity [26,27].

3. System Architecture for P2P Energy Trading

Figure 1 shows the cyber-physical architecture of a group of prosumers in a residential grid. It consists of two main layers: the physical layer and the virtual layer. To enable P2P energy trading, the physical layer is responsible for providing the physical electric network for the transfer of electricity between sellers and buyers. Such a physical network could be the traditional distribution grid for power utility or a separate microgrid distribution grid in conjunction with the traditional grid. The main elements in the physical layer include the grid power connection, metering, and communication infrastructure. The virtual layer provides a secure connection among peers and gives equal access to all participants when deciding on the energy trading parameters for sell/buy orders. Other elements include market participants and regulations.

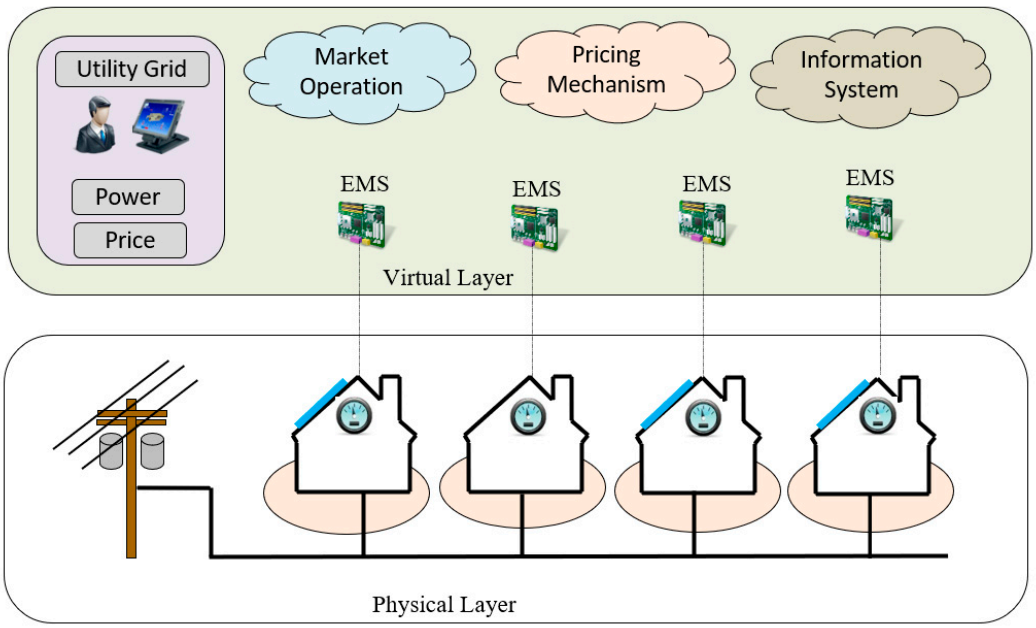


Figure 1. Schematic diagram for the physical layer and the cyber layer of a residential power grid.

To participate in P2P energy trading, a communication infrastructure was required to connect among peers. Such communication infrastructure could be implemented using different wired/wireless communication technologies. The following are the definitions of a peer, microgrid, and community microgrid.

- Peer: it refers to a single entity such as a smart home or a smart building.

- Microgrid: it consists of a collection of loads and distributed energy resources that can operate in a grid-connected mode or an island mode.
- Community Microgrid: it refers to a group of homes and/or buildings that are integrated with distributed energy resources and/or energy storage systems. Additionally, it could operate in both a grid-connected mode and an island mode.

Figure 2 depicts a system architecture diagram for local P2P energy trading in the distribution power system [28]. It consists of five layers: the power grid, communication network, cloud management, blockchain, and application.

- Power Grid Layer: It comprises the actual components of the electrical power system, including generation, storage, and consumption in households/buildings. Examples of the main appliances include HVAC, washing machines, ovens, and electric vehicles. Other elements in the distribution power system include transformers, power feeders, smart meters, etc. The data acquisition is performed using different sensor nodes, meters, measuring devices, RTUs, and IEDs.
- Communication Network Layer: it consists of communication network devices such as routers and switches that enable data transmission using wired/wireless communications. Data are collected from different devices such as smart meters, weather stations, and indoor environment sensors. Examples of wired technologies include Ethernet and power line communication, while wireless technologies include WiFi, ZigBee, mobile network, and LPWAN.
- Cloud Management Layer: this is a middleware layer that provides communication and data services for the upper layers. There are different solutions, such as VM-based, fog, and service-oriented. The cloud layer enables data storage and information retrieval.
- Blockchain Layer: it provides a decentralized distributed ledger that gives great benefits for automated energy trading processes, security, and transparency when sharing information among peers. Blockchain technology can enable the operation of smart contracts and distributed data storage among peers.
- Application Layer: there are different types of applications and services related to monitoring, management, control, and prediction, which can provide added values to the energy solution for all participants, including the utility, prosumer, and consumer.

The size and number of participants determine how energy trading is conducted in the P2P energy trading concept. Such architectures can be divided into three different types, as shown in Figure 3, including the full decentralized P2P architecture (Microgrid 1, Microgrid 3, and Microgrid 4), community-based P2P architecture (Microgrid 2), and hybrid P2P architecture [15,29].

- Full decentralized P2P architecture: each participant can directly negotiate with one another independently without any centralized unit to coordinate the trading among peers. Additionally, the peers have full autonomy over how they manage their own resources (generation/storage/load) with different preferences in energy trading, such as lower prices, serving the community, or using clean energy.
- Community-based P2P architecture: the members of the community share common goals. Each member of the community communicates their requirements for energy trading to a central unit (e.g., the community manager). In such cases, all measurements from the peers are communicated to a central unit (community manager), and such measurements are used to make decisions and take action.
- Hybrid P2P architecture: a combination of both fully decentralized P2P architecture and community-based P2P architectures. The role of the community manager can be used to manage the trading activities between the community members in the same microgrid or between members in different microgrids.

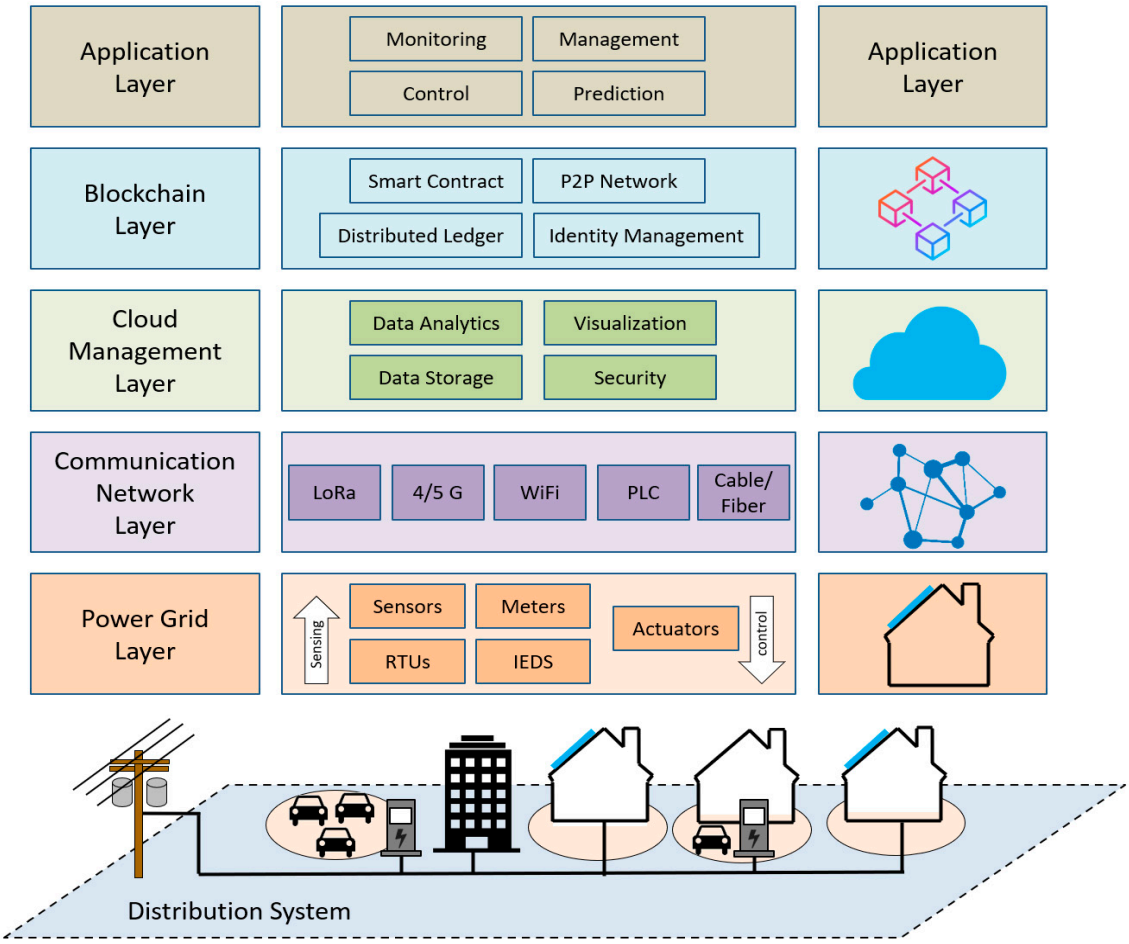


Figure 2. Schematic diagram for the system architecture of local P2P energy trading in distribution power system.

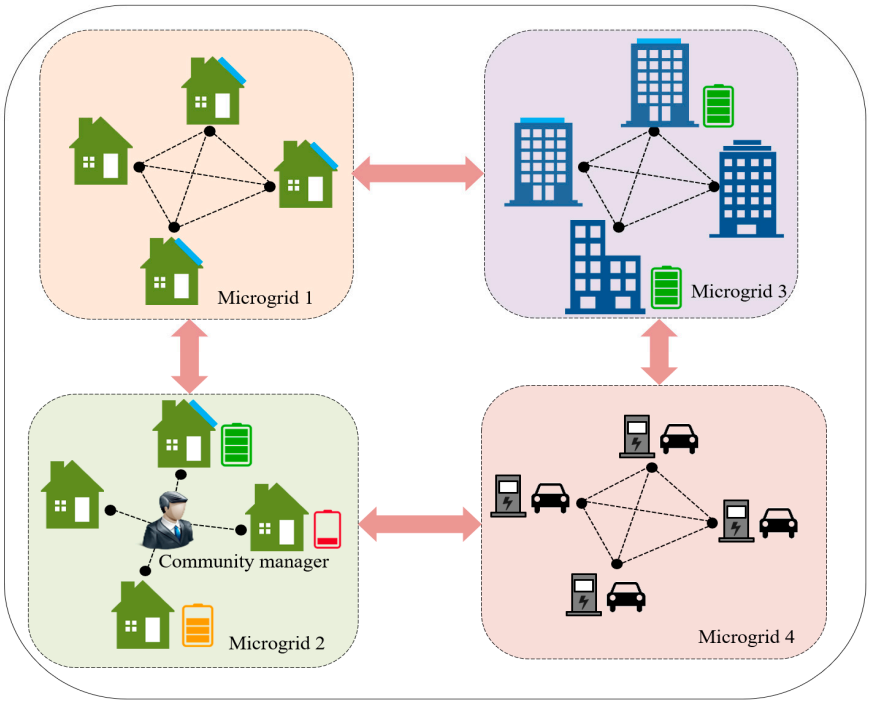


Figure 3. Schematic diagram for different P2P architectures in a community microgrid.

4. Modeling Smart Prosumers in a Community Microgrid

IEC 61850 is the international standard for communications in substations which defines a universal data model to facilitate the interoperability of different equipment and devices [30]. In this work, the IEC 61850-7-420 standard defined the information models which were used in the exchange of information with distributed energy resources (DER) and distribution automation (DA). DERs include connected generation systems, energy storage systems, and controllable loads. The DER management system includes an energy management system (EMS) in the microgrid, community, campus, and building. The DA equipment includes automated switches, fault indicators, and other management devices [31].

In this work, we developed a communication network architecture for smart prosumers based on the IEC 61850 standard's logical node concept. The suggested model was made up of several logical nodes. Each logical node carried several sorts of information, such as analog, status, and control data. Figure 4 shows the communication model for a smart prosumer. The developed communication model used in this work included a PV system, a battery energy storage system, loads, and the power grid. Detailed information for the sensing devices for each subsystem is given in Table 1 based on Ref. [32].

Table 1. Main elements of sensing devices for a smart prosumer.

Element	Sensing Devices
PV System	module temperature, current, voltage, power, tracker azimuth angle, and tracker tilt angle,
Battery System	characteristics of the rectifier, remote monitoring and control of battery charger, remote monitoring and control of battery system
Met. Mast	ambient air temperature, irradiance, wind direction, and wind speed,
Power Grid	current to/from grid, voltage_utility, power to/from grid

We considered that each smart prosumer included a home energy management system "local controller". This unit was responsible for the real-time monitoring and control of home appliances as well as optimizing local power generation, storage, and consumption. With respect to communication networks, the focus would be given to the commonly available technologies, including Ethernet and WiFi, for the feasibility of implementing this system in a real scenario for HAN [33] and NAN. The communication range of Ethernet and WiFi was suitable for HEMS to communicate with the sensor nodes and measurement devices in the community microgrid.

We considered that each smart prosumer included a small metrological station. Table 2 shows the measuring requirement for different sensors, including the temperature, irradiance, wind speed, and wind direction. Table 3 shows the configurations of IEDs such as P&C-IED, MU-IED, and CB-IED, while Table 4 shows the type of data and data size. The monitoring scope and control scope is given in Table 5.

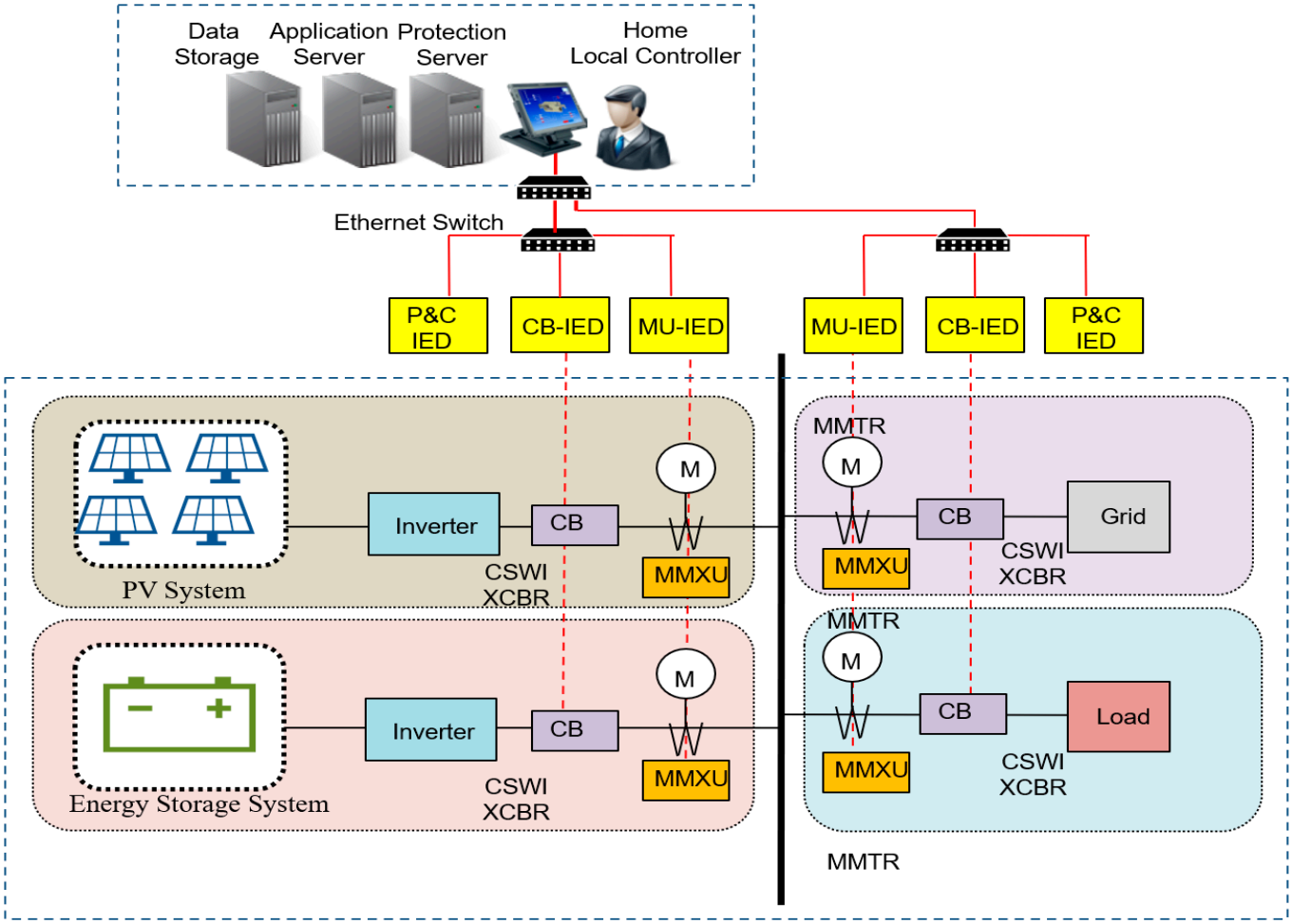


Figure 4. Communication model for a smart prosumer based on the IEC 61850 standard.

Table 2. Measuring requirements for the meteorological station.

Measurement	Ambient Temperature	Irradiance	Wind Speed	Wind Direction
Sampling Frequency	1 Hz	100 Hz	3 Hz	3 Hz
Number of Channels	1	1	1	1
Data Rate	2 bytes/s	200 bytes/s	6 bytes/s	6 bytes/s

Table 3. Configurations of IEDs.

	PV System	Energy Storage System	Load
CB-IED	1	1	1
MU-IED	1	1	1
P&C IED	1	1	1

Table 4. Data type and size for IEDs.

IED Type	CB-IED	MU-IED	P&C-IED
Data Type	Status of Breaker	Current and Voltage	Control information
Data Size	16-bytes	76,800-bytes	76,816-bytes

Table 5. Monitoring scope and control decisions.

	Generation	Storage	Protection IEDs	Load
Scope	Output Control	charge/discharge Control	Control and Protection	monitoring and control load
Connectivity	GC→HEMS	BESS→HEMS	IED→HEMS	LC→HEMS

The communication infrastructure is the heart of the P2P energy trading system. It enables each peer to access their own energy information locally, as well as share information with other peers based on the configured topology architecture. The communication infrastructure must be reliable and fulfill the requirements of the P2P energy trading system. With the increase in many services that request data from different microgrid components (prosumer, consumer, service provider), the communication infrastructure must be able to support data transfer and the capability of real-time monitoring and control [34,35]. Table 6 shows the communication requirements for the microgrid systems in view of the latency, throughput, and security to support different applications, including distributed energy resources and storage, such as smart meters, home energy management, and home automation.

Table 6. Microgrid time requirements for different applications.

Requirements	DER and Storage	Smart Meter	HEMS	Home Automation
Latency	15 s	Variable	300 ms–2 s	seconds
Throughput	96–56 kbps	10 kbps	9.6–56 kbps	4.8–48
Reliability	99–99.9%	>98%	>98%	>98%
Security	High	High	High	High

5. Simulation Results

There are different simulation tools that can be used to evaluate the network performance, such as NS-3, OMNet++, and OPNET. The OPNET Modeler is a network simulator that supports many library functions and different network protocols [36]. In this work, the OPNET Modeler was used for the modeling and simulation of the communication network. This software was user-friendly and included all network devices that could be used to build and configure complex network topologies. We considered a case study with 10 prosumers to assess the performance of the communication infrastructure (smart prosumers integrated with renewable energy resources). The OPNET Modeler was used to evaluate the communication network performance with different numbers of prosumers. The dimension of the site was based on the real dimension of the residential area in Riyadh City, Saudi Arabia.

The microgrid is a localized power grid that is integrated with distributed energy resources, an energy storage system, and loads which can be operated in a grid-connected mode with the main grid or a standalone mode that is independent of the grid. Based on the scale, a small microgrid can be a single home or a single building, while a large-scale microgrid can span a group of buildings, hospitals, or university campuses [37]. In this work, two scenarios were considered: the HAN of a standalone microgrid system for a "smart prosumer" and the NAN of a community-based P2P architecture with a group of prosumers.

5.1. Scenario 1: HAN Results for a Smart Prosumer

For the smart prosumer scenario, the communication links of the wired-based architecture were configured with a channel capacity of 100 Mbps and 1 Gbps. For the wireless-based solution, WiFi technology was configured using different data rates, including 54 Mbps, 24 Mbps, and 11 Mbps. Figure 5 shows the Ethernet-based architecture, while Figure 6 shows the network model using the WiFi-based architecture.

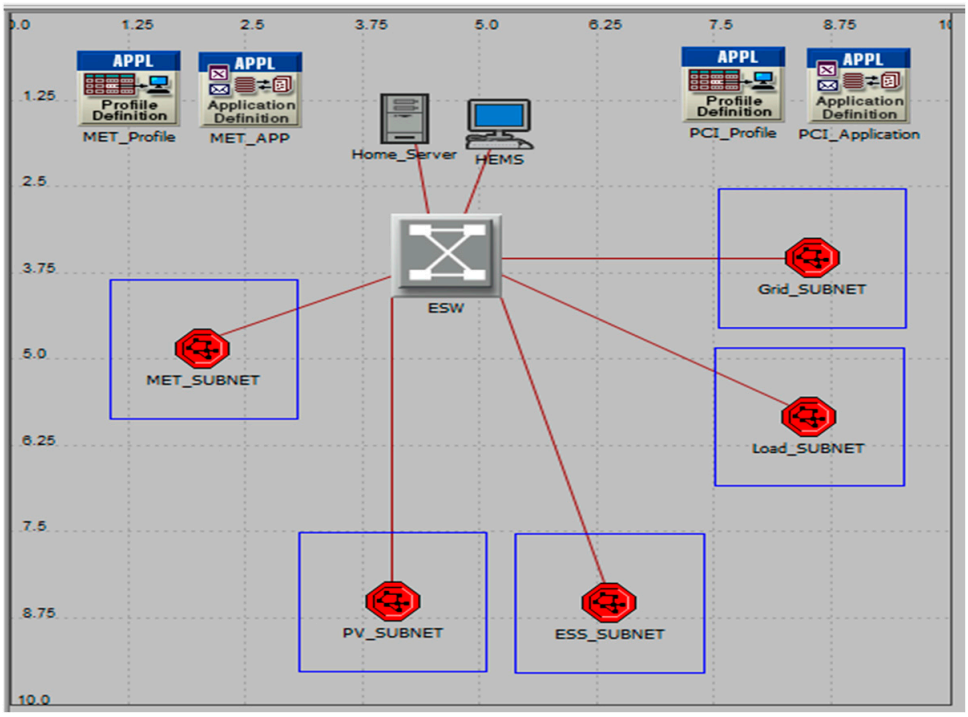


Figure 5. Ethernet-based communication network model for the smart prosumer.

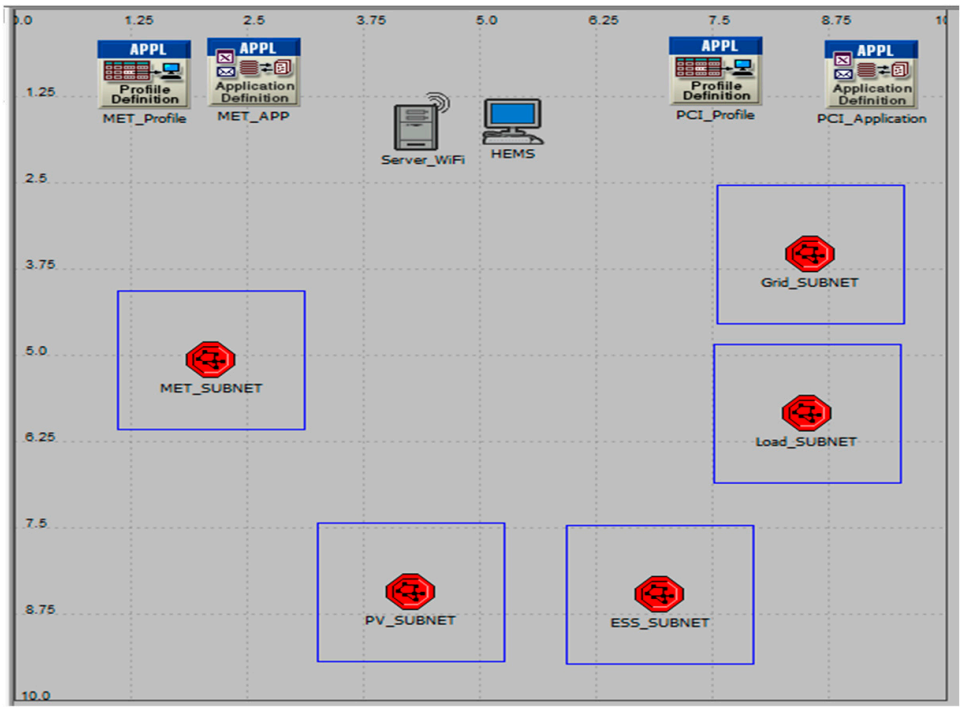
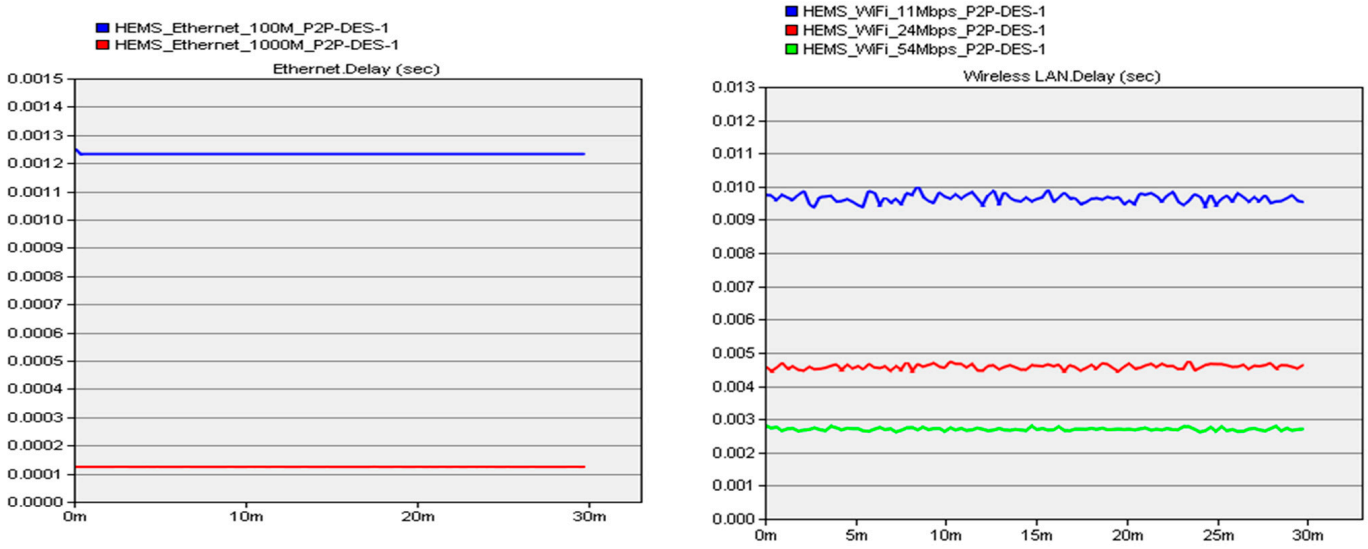


Figure 6. WiFi-based communication network model for the smart prosumer.

Figure 7 shows the simulation results of HAN for a smart prosumer, while Table 7 shows a summary of the average end-to-end delay in six different scenarios. For the smart prosumer, the average end-to-end delay was about 0.123 ms and 1.23 ms using a communication link with the Gigabit Ethernet and Fast Ethernet, respectively. In the case of the WiFi-based architecture, the average end-to-end delay was about 9.64 ms, 4.57 ms, and 2.69 ms, using the data rates of 11 Mbps, 24 Mbps, and 54 Mbps respectively.



(**a**) (**b**)

Figure 7. End-to-end delay for a smart prosumer scenario. (**a**) Ethernet with a channel capacity of 100 Mbps and 1 Gbps; (**b**) WiFi with data rate of 54 Mbps, 24 Mbps, and 11 Mbps.

Table 7. Average end-to-end for different scenarios for a smart prosumer.

	Ethernet	Average ETE Delay (s)	WiFi	Average ETE Delay (s)
Smart Home	HAN (100 Mbps)	0.00123	HAN (54 Mbps)	0.00269
	HAN (1 Gbps)	0.000123	HAN (24 Mbps)	0.00457
			HAN (11 Mbps)	0.00964

5.2. Scenario 2 NAN Results for Community-Based P2P Architecture

For NAN, the communication channels for the wired-based architecture were set up with channel capacities of 100 Mbps and 1 Gbps. For the community-based P2P architecture scenario, WiFi with different data speeds of 54 Mbps, 24 Mbps, and 11 Mbps was configured. The Ethernet-based design is depicted in Figure 8, while the WiFi-based network model is shown in Figure 9.

Table 8 shows the results of the end-to-end delay for the community-based P2P architecture. With 10 smart prosumers, the end-to-end delay was about 12.86 ms and 1.27 ms for the fast Ethernet and Gigabit Ethernet, respectively. The network performance satisfied the delay requirement for the different microgrid applications given in Table 6. However, for a WiFi-based architecture, stable performance was achieved with six prosumers (54 Mbps), five prosumers (24 Mbps), and four prosumers (11 Mbps), as shown in Table 9. The network performance was not stable in the case of 10 prosumers (54 Mbps), 7 prosumers (24 Mbps), and 6 prosumers (11 Mbps).

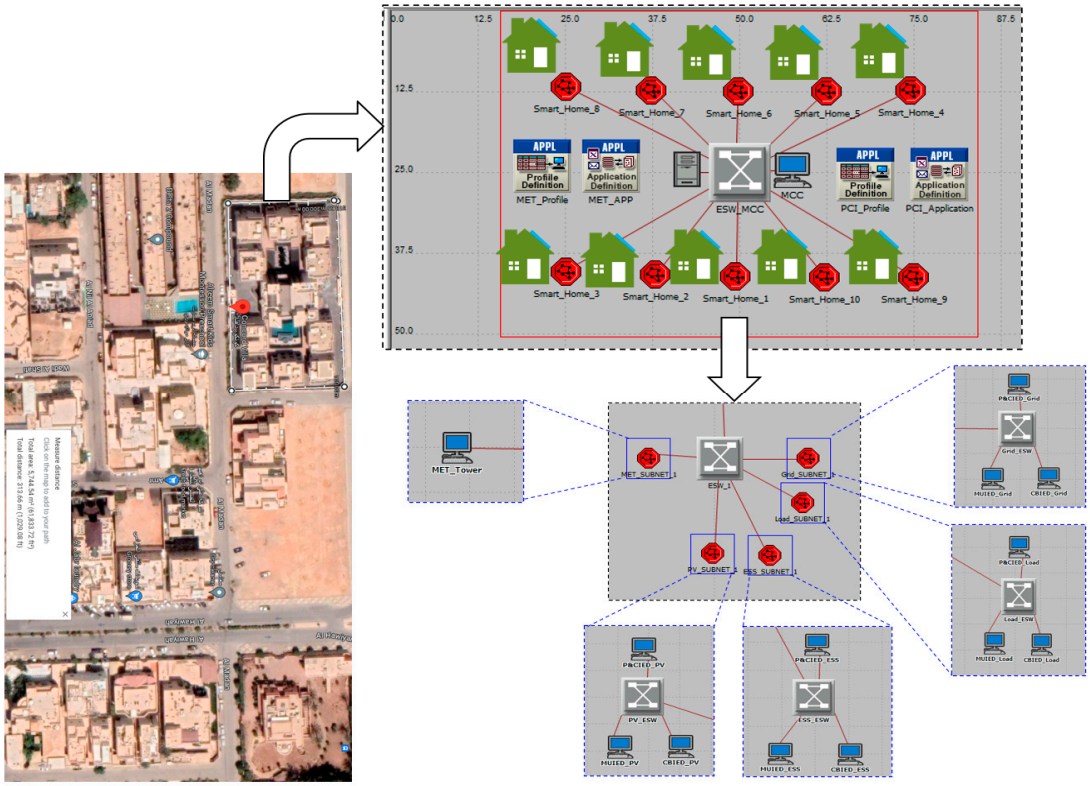


Figure 8. Ethernet-based communication network model for community-based P2P architecture with 10 smart prosumers.

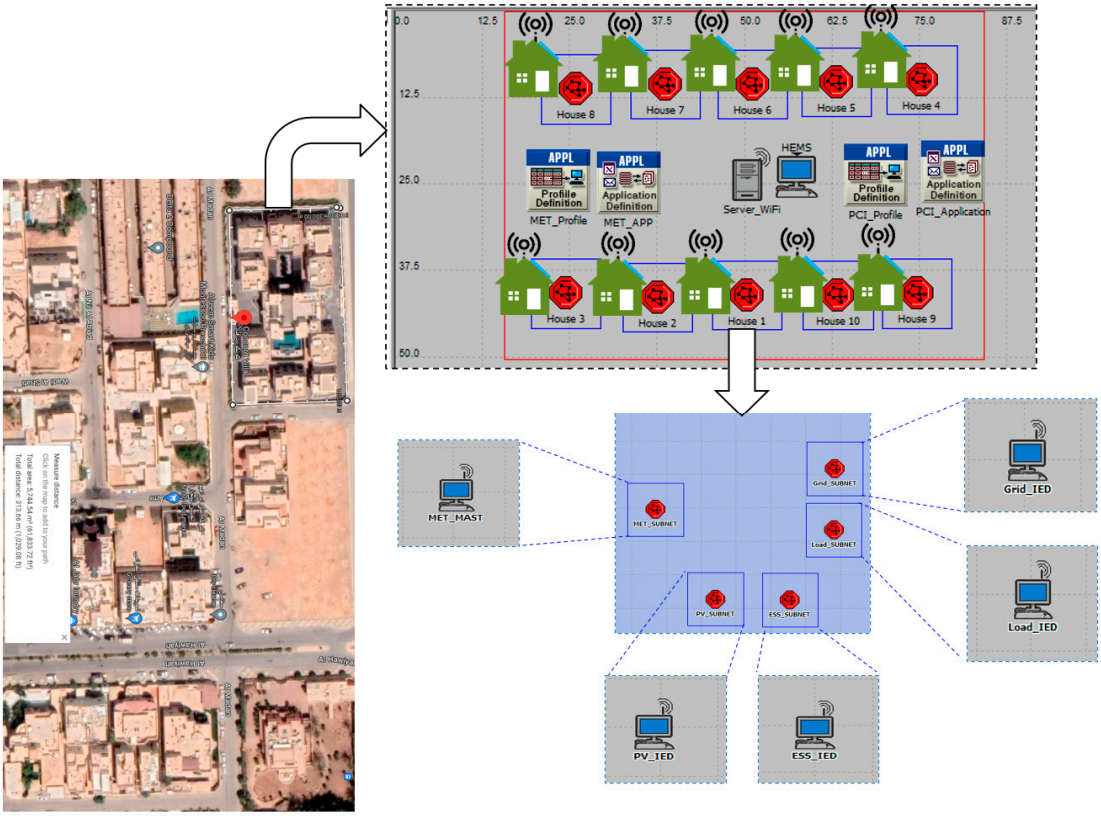


Figure 9. WiFi-based communication network model for community-based P2P architecture with 10 smart prosumers.

Table 8. End-to-end delay (second) for NAN based on Ethernet-based architecture for community-based P2P. Smart Prosumer (SP).

Scenario	Fast Ethernet (100 Mbps)	Gigabit Ethernet (1000 Mbps)
1 Prosumer	0.00123	0.000124
2 Prosumers	0.00247	0.000252
3 Prosumers	0.00371	0.000379
4 Prosumers	0.00510	0.000506
5 Prosumers	0.00621	0.000635
6 Prosumers	0.00753	0.000764
7 Prosumers	0.00878	0.000893
8 Prosumers	0.01021	0.001022
9 Prosumers	0.01149	0.001151
10 Prosumers	0.01286	0.001279

Table 9. Average end-to-end delay (second) for NAN based on WiFi-based architecture for community-based P2P.

Scenario	WiFi (54 Mbps)	WiFi (24 Mbps)	WiFi (11 Mbps)
1 Prosumer	0.00266	0.00452	0.00959
2 Prosumers	0.00451	0.00774	0.00774
3 Prosumers	0.00700	0.01213	0.01213
4 Prosumers	0.00919	0.01615	0.01615
5 Prosumers	0.01175	0.02620	0.44411
6 Prosumers	0.01507	0.20364	-
7 Prosumers	0.01791	-	-
8 Prosumers	0.02663	-	-
9 Prosumers	0.12120	-	-
10 Prosumers	-	-	-

5.3. Discussion and Limitations

The microgrid communication infrastructure is set to play an essential role in the real-time monitoring and control of peer-to-peer energy trading. To ensure its reliable and stable operation, various characteristics of communication technology, such as coverage, latency, and throughput, need to be evaluated. The results show that Ethernet-based communication architectures were sufficient for data sharing among peers at the HAN and NAN levels, with an end-to-end delay of 1.23 ms and 12.86 ms for a standalone prosumer and 10 prosumers, respectively. However, WiFi-based communication architectures were sufficient for a small number of participants. The end-to-end delay was about 2.66 ms and 121.2 ms for a standalone prosumer and 10 prosumers, respectively. To extend the current work, the main directions are given below:

- It is crucial to define the type and nature of peer-to-peer energy trading. There are different types of market mechanisms among peers, including centralized, decentralized, and distributed. Although this work is considered a centralized market mechanism based on the business model, other market mechanisms need to be investigated and compared.
- Microgrid subsystems cannot be monitored and controlled through a single communication network and/or technology. Although this work considered two different communication technologies, Ethernet and WiFi, further investigations are required for data transmission using heterogeneous communication technologies among different subsystems.
- Peer-to-peer energy trading is susceptible to different types of attacks which could compromise the microgrid infrastructures, including the physical and cyber layers. A thorough analysis of these types of cyberattacks, vulnerabilities, and countermeasures are very important elements to be investigated.

- Peer-to-peer energy trading is a complex cyber-physical system that is still in its early stage. Experimental work needs to be conducted to address the challenges of different physical and cyber layers, as well as to validate and compare the simulation results with real system implementations.

6. Conclusions

Peer-to-peer energy trading could provide new opportunities for future smart grids. In order to implement such systems, communication infrastructure is crucial in data transmission for monitoring, operation, and control. For a smart prosumer in a community microgrid, we developed a communication network model in this study. This model was on the IEC 61850 standard and included a PV system, a battery energy storage system, loads, and a grid connection. The smart prosumer model could be extended to include additional energy sources, such as wind turbines, electric vehicles, etc., owing to the modular design of the communication model. Two scenarios were considered: the HAN for a smart prosumer and NAN for a community-based P2P architecture. To evaluate the network performance, this work considered the commonly available technologies of Ethernet and WiFi for implementation. The simulation results showed that both Ethernet and WiFi technologies could satisfy the delay requirement for monitoring and control if the appropriate selection of channel capacity and data rate were selected. The end-to-end delay was about 12.86 ms and 1.27 ms for community-based P2P (10 prosumers) using the Fast Ethernet and Gigabit Ethernet, respectively. The average end-to-end delay was about 11.75 ms, 26.20 ms, and 444.11 ms for the WiFi-based architecture of a community-based P2P (5 prosumers) using different data rates of 54 Mbps, 24 Mbps, and 11 Mbps, respectively.

Although this work considered Ethernet and WiFi for the performance evaluation, other wired/wireless communication technologies need to be considered. Our current efforts are focused on putting the entire system into practice in order to verify these network performance findings. Furthermore, other communication technologies will be considered, such as BLE for HAN and LoRa for NAN, as well as a hybrid P2P architecture.

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