Cybersecurity in Next Generation Energy Grids: Challenges and Opportunities for Blockchain and AI Technologies

Notis Mengidis, Theodora Tsikrika, Stefanos Vrochidis and Ioannis Kompatsiaris

Abstract Renewable energy sources and the increasing interest in green energy has been the driving force behind many innovations in the energy sector, such as how utility companies interact with their customers and vice versa. The introduction of smart grids is one of these innovations in what is basically a fusion between the traditional energy grid with the IT sector. Even though this new combination brings a plethora of advantages, it also comes with an increase of the attack surface of the energy grid, which becomes susceptible to cyberattacks. In this work, we analyse the emerging cybersecurity challenges and how these could be alleviated by the advancements in AI and blockchain technologies.

Keywords Cybersecurity, Blockchain, AI, Energy Grid, Smart Grid, Smart Contracts, Consensus Algorithms

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1.Introduction

In past decades, the development of power grids has not been keeping pace with industrial and societal advancements that have created an increased demand of power supply. According to (Ratner and Glover 2014),during the period from 1950 to 2014, just in the US, energy production and consumption increased more than two and three times respectively. With this increased demand of electricity, issues like voltage spike and sags, blackouts, and overloads have increased as well, resulting in availability issues which consequently lead to revenue losses for the energy industry. As an example, a study conducted by (Knapp and Samani 2013) indicated that the American economy loses annually approximately $150 billion due to power interruptions. Furthermore, the power industry alone produces up to 40% of United States' carbon dioxide emissions (Liu et al. 2012), a percentage slightly lower within the European Union (Rootzén 2012).

To cope with the aforementioned shortcomings of the energy industry, the need to efficiently manage a variety of energy sources became evident. It also became clear that legacy power systems can no longer meet the requirements of modern society in terms of reliability, scalability, manageability, and cost-effectiveness. These needs gave birth to *smart grid*, a dynamic and interactive infrastructure with new energy management capabilities, which however inevitably created a system with potential vulnerabilities in terms of cybersecurity. In this paper, we present some of the most emerging cybersecurity challenges related to smart grid and discuss mitigation techniques based on blockchain and AI.

2. Background

Section 2 provides a detailed overview on what consists a smart energy grid, its main components and a high-level description on the communication protocols used by its elements. We also present how blockchain technology works and the different types of existing system architectures and consensus algorithms.

2.1 Overview of smart grids

The smart grid can be considered as the next evolution step in today's power grid technology and smart meters specifically are the corner stone of this evolution. In case an energy provider decides to shift towards a smart grid implementation, the first step is to install a smart meter in every customer and premises. Smart meters are devices that offer the capability both to the provider and to the customer real-time (or near real-time) monitoring of electricity consumption or production, in the case of e.g. photovoltaic cells. They also offer the possibility to read the measurements locally and remotely, and

additionally allow the provider to limit or terminate the supply of electricity where appropriate.

The National Institute of Standard and Technology (NIST) defines the smart grid as a composition of seven domains: bulk generation, transmission, distribution, customers, markets, service providers, and operations (Greer et al. 2014). The first three domains are responsible for the power flow, whereas the last four correspond to the part of the energy grid responsible for data collection and power management. In order to interconnect the aforementioned domains, a backbone network is required which can be broken down to smaller local-area networks. Figure 1 illustrates how this interconnection takes place in a logical as well as in a network level.

On a higher level, a smart grid consists of four main components; the Advanced Metering Infrastructure (AMI), the Supervisory Control and Data Acquisition (SCADA), the plug-in hybrid vehicle (PHEV), and various communication protocols (Halim et al. 2018). AMI's role is measuring and analyzing energy usage and allows a two-way communication between the consumer and the utility company.

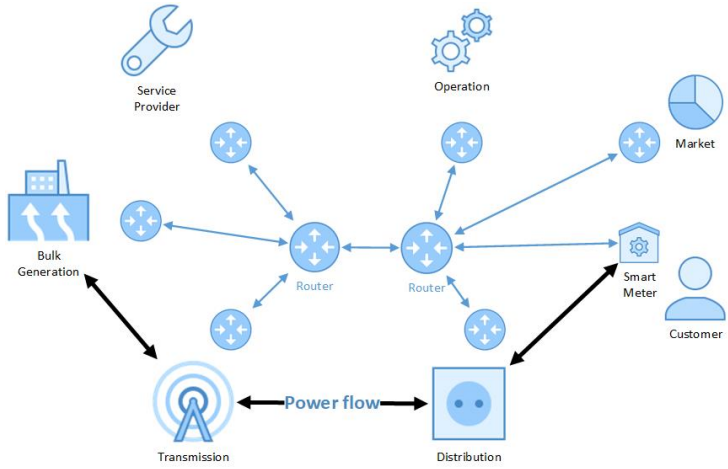

Fig. 1.1 Network architecture of the smart grid

Smart meters communicate with the AMI headend, which aggregates the information from a large number of meters, and relay the aggregated data to the Meter Data Management System (MDMS). Communication between the smart meters and the AMI headend is usually achieved through wireless links such as Wireless Sensor Networks (WSN) (Len et al. 2007), cellular systems (Mohagheghi et al. 2009) or even cognitive networks (Ghassemi et al. 2010).

As a result of the highly-distributed nature of the AMI network and the openness of the wireless communication medium, we are motivated to examine the cybersecurity challenges that arise due to the increased attack surface and investigate the opportunities that this early stage of smart meters' adoption has to offer.

2.2 Overview of blockchain technologies and consensus algorithms

The idea of cryptocurrencies was first perceived by David Chaum in his proposal for untraceable payments (Chaum 1983) where he described a system where third-parties are unable to determine payees and time or amount of payments made by an individual. He took his idea one step further in 1990 by creating the first cryptographic anonymous electronic cash system, known as ecash (Chaum et al. 1990). Later in 90s, a lot of startups emerged trying to implement electronic cash protocols, attempts that ultimately failed.

Cryptocurrencies, as we know them today, are peer-to-peer decentralized digital assets based on the principles of cryptography. Most cryptocurrencies use a distributed database as the pillar of their system, known as blockchain, which allows them to use it as a distributed public ledger without having to rely to any form of centralized control similar to banking systems.

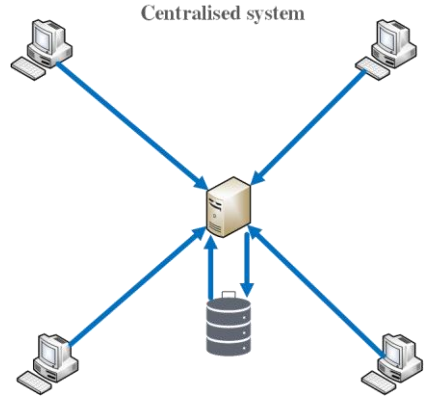

Fig. 2.1 A single trusted authority holding a copy of the ledger

The blockchain is the equivalent of a book maintained by a bank which contains all the accounts and each transaction made. Of course, this is an oversimplification and in reality, there are many differences, possibly the most noticeable being the fact the bank's records are private whereas the blockchain is publicly available and easily accessible by everyone. One of the most interesting aspects of blockchains is that they contain the records of every transaction made since the beginning, also known as genesis block, by using a peer-to-peer distributed timestamp server which generates computational proof of the chronological order of the transactions (Nakamoto 2009)

Blockchains in general require a network to run and transmit their data. In the context of cryptocurrencies, this transmission is equivalent of copying coins from one electronic wallet to another, and here is where the biggest challenge lies; how to ensure

that every coin is spent only once. Whereas the traditional approach for such a problem would be to rely on a centralised authority that would validate the status of each transacting party, blockchain solves this problem by allowing everyone in the network to have their own copy of the historic log of all transactions. This however creates another issue, which is how we can make all transacting parties to agree upon the validity of the state of the ledger. Depending on the type of blockchain used, there are many proposed validation techniques, however in principal all these techniques are called distributed consensus algorithms.

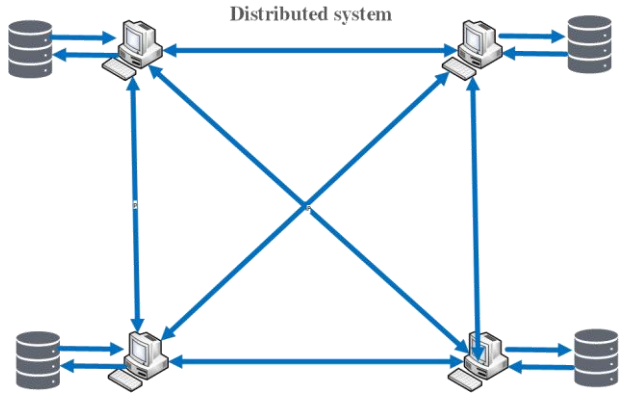

Fig. 2.3 A distributed platform where each node has a copy of the ledger

As shown by (Baliga 2017), a resilient consensus algorithm in terms of reliability, node failure and malicious activities can be a quite challenging process. There are many proposed consensus algorithms, each with its own strengths and weaknesses. In general, these algorithms can be classified into two broad categories, namely lottery-based and voting-based (Andoni et al. 2019).

The first category of algorithms consists of proof-of-work (PoW) algorithms, which are the most commonly used ones by cryptocurrencies such as Bitcoin and Ethereum, and proof-of-stake (PoS) algorithms. In PoW algorithms, the consensus is achieved by solving cryptographic puzzles which depending on the computational power that each node offered, rewards them with their fair amount of votes in the network. On the other hand, in PoS algorithms, the weight of the vote is determined by the size of the stake that each node has in the network, eg the amount of cryptocurrency deposited or mined in a wallet.

The second generic category of consensus algorithms are the voting-based systems where the validation is achieved through a multi-round process where all nodes vote for the next block candidate to be included in the blockchain. As soon as the voting ends, the validating nodes have to agree on whether or not the voted block will be accepted in the network. Since the votes are transmitted in a potentially untrusty network and the trustworthiness of each node cannot be ensured, the design of such a system has to be carefully considerated. Starting with Bitcoin's PoW, we are going to present the most popular consensus algorithms.

2.2.1 Proof of Work (PoW)

Hashcash (Back 2002) was the first time a PoW mechanism was used, even though it was developed for a different purpose than cryptocurrencies; the mitigation of denial of service attacks towards internet resources. Proof of work algorithms became more widely known when Bitcoin used one variant of such algorithm in order to validate newly added blocks in its network. The algorithmic approach of Bitcoin involves a random number (nonce) that it can be used only once and it is the hashed value of the block header. Each miner then competes in order to find a hashed value that it lower than the nonce. Since there is no way to determine whether the hashed value will be actually lower than the nonce, the only feasible action is through continuous trial and error, similar to a computationally expensive brute force attack.

When a transaction is transmitted to the network, it is then subjected to validity checks and it is not verified until it becomes part of the blockchain. New transactions constantly flow in the network and they get added to a memory pool of unconfirmed transactions handled by each node. Since the size of each block is finite, transactions have to deal with competition in order to be added in the new block and the selection criteria is based on who paid the highest fee.

As nodes build a new block, they add unconfirmed transactions from the memory pool to a new block and attempt to solve a computationally intensive problem to prove that the block is valid. This is the proof-of-work concept of Bitcoin and the process of solving it is called mining. Mining ensures that transactions are only con-firmed if enough computational effort was spent on the blocks that contain them. More blocks mean more effort which subsequently means more trust (Antonopoulos 2014).

To incentivize mining, each mining node includes a special transaction in its block containing a transaction that pays its own address a reward (currently 12.5 BTC per block) of newly created Bitcoins. If the node finds the solution before the other nodes in the network, then the block becomes valid, and it wins the reward since the block is added to the blockchain, thus the reward transaction becomes spendable. This reward transaction is the only exception to the rule that a transaction's outputs has to be smaller or equal to its inputs.

The block is then propagated throughout the network and contains a list of transactions that the node which created the block committed since the previous block (Decker and Wattenhofer 2013). To prevent denial-of-service attacks and spam, every node that receives this newly created block validates it before forwarding it further. If it determines that it is a valid block then it propagates it to its adjacent nodes, discards its previous mining efforts, applies the transactions from the current block and immediately starts working on building the next block.

At this point, the network has agreed on the validity of the transactions contained in the newly mined block and the transactions are confirmed and do not have to be reapplied. The transactions that were not included will have to be validated again and reapplied on top of the new block state.

One of the main disadvantages of PoW is that it requires large amounts of electricity. According to (Pilkington 2016), Bitcoin could one day consume up to 60% of global electricity production, 13,000 terawatt hours, equal to powering 1.5 billion homes. Another report from (Deetman 2017) claims that the increase in electricity consumption of the bitcoin network may lead to a draw of over 14 Gigawatts of electricity by 2020, equivalent to the total power generation capacity of a small country, like Denmark.
Another drawback in PoW design, is that if a mining entity (either a mining pool or an individual miner) managed to contribute more than half of the network's hash rate, then that entity would have total control of the network and would be able to manipulate the blockchain at will. This is often called the 51% attack even though it has been proved that actually less hash power suffices to perform this kind of attack (Eyal and Sirer 2018).

To have a better understanding of this attack, let's assume two blockchains, which both have a common ancestor, with lengths *n* and m *(n > m)*. If n is the honest chain and m the chain of the attacker (who has more than half of the network's hash rate), then both counterparts can create a chain with length $k > n$ with probability $p^{(k-l)}$, where l is the current chain length and p the percentage of the attacker's hash rate. Evidently, if the attacker picks a *k* large enough, he will have a bigger probability of finding a longer chain than the honest one.

2.2.2 Proof of Stake (PoS)

The inherent weaknesses and the subsequent criticism of PoW lead to the development of a new distributed consensus algorithm. In PoS the creator of the new block is selected through a combination of randomness and wealth or age which called stake. The chance of a node getting selected is usually proportional to the amount of wealth that the specific node has invented into the network, however a certain amount of randomness is also introduced in order to avoid the case where the wealthiest member of the network has an advantage and gets selected all the time.

This approach offers greatly reduced power consumption and are less susceptible to 51% attacks, however they arise the issue of *nothing-at-stake,* where the nodes that have nothing to lose, vote for multiple blockchain candidates hence preventing the chain to reach a consensus state. Since the cost for such attempts is little to none, some blockchains adopting PoS algorithms are prone to fake states attacks (Kanjalkar et al. 2019).

2.2.3 Delegated Proof of Stake (DPoS)

In Delegated Proof of Stake (DPoS) the nodes in the network, instead of voting for the validity of the blocks, vote to elect a number of so-called *witnesses*, that will generate blocks on their behalf. After a predetermined interval has elapsed, the witnesses are shuffled and new witnesses are allowed to produce blocks per *n* number of seconds (*n* depends on the implementation). After each round, witnesses are rewarded according to

the amount of blocks they produced, however failure to do so means an increase in the probability of being voted out in the next round (Bach et al. 2018). Some of the advantages of DPoS include greater scalability compared to PoW, faster verification times, and energy efficiency. However, since the number of witnesses in the network are somehow limited, the danger of centralization is apparent.

3. Cybersecurity Challenges

Cybersecurity poses one of the largest and multifaceted challenges that the smart energy grid and the IoT ecosystem in general will have to address in the years to come. Given the number of interconnected sensors, devices and networks that constitute a smart grid, it becomes evident that it is susceptible to online probing, espionage, and constant exploitation attacks by malicious actors aiming at disrupting the stable and reliable energy grid operation, obtaining sensitive customer information, as well as threatening the CIA triad (confidentiality, integrity and availability) of the network (SGC Committee 2014). In order to have a clearer picture of the dangers posed by the integration of smart energy meters in the traditional energy grid, we will examine the security requirements of a smart grid and analyse the most high-profiled challenges from a cybersecurity perspective.

3.1 Cybersecurity Requirements and Objectives in the Smart Grid

According to NIST, the main criteria required to ensure the security of information in any given information system, thus smart grid as well, are *confidentiality*, *integrity* and *availability, also known as the CIA triad* (SGC Committee 2014). It is also widely accepted that *accountability* is another important aspect of security, therefore it will also be included as an additional criterion below (Liu et al. 2014).

3.1.1 Confidentiality

Generally, confidentiality is the preservation of authorised restrictions on information access and disclosure, including means for protecting personal privacy and proprietary information. Once an unauthorised entity, individual, or process gains access to proprietary information, we consider that the confidentiality of the specific system is lost. In the context of the smart energy grid, information such as the past and present measurement values of a meter, consumption usage, and billing information are considered confidential and hence must be protected. Most utility providers nowadays offer electronic bills and some of them even web portals with real-time statistics of

energy usage for each customer individually. With this increased accessibility of consumer data on the internet, confidentiality is starting to become increasingly significant (Yang et al. 2011).

3.1.2 Availability

Availability is defined as the provision of timely and reliable access to and use of information and services. In the case of the smart grid, availability can arguably be considered as the first priority since an availability loss in the grid can potentially have a serious adverse effect on organisational operations, organisational assets and individuals. An availability attack takes place in the form of traffic flooding, where the attacker aims to delay or disrupt message transmission (Lu et al. 2010), or buffer flooding where the malicious actor aims to overwhelm the AMI's buffer with false events (Jin et al. 2011). Both attacks fall under the umbrella of Denial of Service (DoS) and the main objective of the attacker is to exhaust the computational resources of the smart grid and degrade the network communication performance of the grid.

3.1.3 Integrity

Integrity in smart grid is ensuring that there will be no kind of violation of data, including destruction, modification or loss of information while maintaining consistency and accuracy (Siozios et al. 2019). In smart grids, malicious alteration and tampering of critical data in sensors, meters, and command centers can be divided into three major categories. First, there is the integrity of the information in the network, which includes price information and power consumption. In addition, there is the integrity of the software running on the devices, and finally there is the integrity of the hardware which is somewhat of a more cyber-physical challenge. For instance, a set of compromised smart meters whose readings have been altered by the attacker can be considered as an integrity attack (Giani et al. 2011).

3.1.4 Accountability

Accountability is ensuring that every action in any given system can be traced back to the person or entity that performed it. This way, all the information can be used as evidence without anyone being able to dispute the chain of custody of the information or question the non-repudiation of the system. An example of an accountability attack concerns the monthly electricity bill of the consumers. Typically, a smart meter is able to determine and report the customer's power consumption on a daily basis. However, if

a meter is under attack and its readings are altered, then the customer will end up with two separate readings, one from the meter and one from the utility company.

3.2 Cybersecurity Threats and Weaknesses

In this section, we will identify four of the most prevalent cybersecurity challenges that stem from the integration of IT with traditional energy grid systems. Also, we will see how most of the challenges emanate from our need to defend the CIA triad which we analysed in section 3.1

3.2.1 Cyber-attacks

Cyber-attacks on smart grids are a very commonly discussed topic due to the vulnerabilities existing in the grids' communication, networking, and physical entry points. Attacks in the smart grid environment can be categorised into two broad categories (Bou-Harb et al. 2013):

- **Passive attacks**: these are attacks that do not intend to affect system resources and their sole purpose is to extract system information (Cui et al. 2012). In these kinds of attacks, the attacker's objective is to learn or use information that it is transmitted, or to retrieve information stored in the system. Generally, passive attacks are relatively hard to detect, since no alteration of data takes place, thus the best defense against them is prevention through solid security mechanisms.

- **Active attacks**: these attacks are aimed towards a system's resources and attempt to either modify or disrupt them. The most common actors in these kinds of attacks are malicious users, spyware, worms, Trojans, and logic bombs (Gunduz and Das 2018). According to (Gai and Li 2012), the most ordinary types of these attacks are device attacks, data attacks, network availability attacks, and privacy attacks, whereas (Wang and Lu 2013) classify the attacks as those targeting availability, those targeting integrity, and finally those targeting confidentiality.

3.2.2 Trust

Varying requirements exist for operations performed in smart grids. The system consists of the power grid itself, the communication network, and the devices controlling the process (McDaniel and McLaughlin 2009). Honesty and trustworthiness are essential behaviours in the relationship between the consumer and the utility company, thus the

validity of the energy bill of the consumed energy is of vital importance from the consumer point of view, whereas the energy provider needs a trustworthy and fully auditable reporting tool for each operating device in the grid. These demands create new challenges that need to be addressed in an environment that all entities cannot be considered as trusted. Therefore, a trusted intermediary entity needs to decide upon the status validity of the devices and manage the access policies for the network, in a way that can authentically report the current state of the network to third parties.

3.2.3 Single Point of Failure

From a reliability perspective, it is well documented that a single point of failure is one of the biggest concerns in a master-slave architecture. In smart grids, a DDoS attack could disrupt, delay, or prevent the flow of data and eventually even collapse the AMI network. This denial of data exchange means a loss of control messages and may affect the power distribution to the customers in the smart grid.

In the UK, there were concerns regarding the way a proposed national Data Communication Company (DCC) was going to be set up, something that created significant delays to the rollout of the SMETS2 smart metering standard (Meadows 2018). This centralized way of gathering smart meter data is a good paradigm of why a single data authority such as DCC, hence a single point of failure, should be avoided.

From a scalability perspective, the number of the clients is limited by the capacity of the AMI network in terms of bandwidth and routing capabilities, and the latency is determined by the round-trip time (RTT) between the AMI head-end and the devices in the network. In addition, as related research shows (Rodrigues et al. 2016), there is an exponential growth of IoT devices, a trend that will likely be followed by smart energy meters as well. Therefore, scalability is emerging as one of the key factors for energy grid development and exploitation, considering the technical challenges connected with the geographical distribution over broad areas and the connectivity and resource availability in general (Bellavista and Zanni 2016).

3.2.4 Identity and Access Management

One issue with smart meters in smart grids is the management of the cryptographic keys that are required by every meter for cryptographic computations, such as the encryption of the transmitted data. Before the deployment of the AMI, the confidentiality of customer privacy and customer behaviour, as well as message authentication for meter reading, and control messages must be ensured. This can be solved by encryption and authentication protocols which depend on the security provided by cryptographic keys. The current industry standard is the use of a X.509 certificate for identification and for establishing a secure connection during data transmission. However, these cryptographic keys remain static for the whole life-cycle of the meter, and a key management

mechanism that would allow manufacturers to periodically update or revoke them does not seem to be currently implemented. Furthermore, since such keys are also considered a form of strong device recognition, an attacker could possibly abuse the private key of the device (Baumeister 2011) and enable access to the device by unauthorised parties, or even potentially impersonate the device in the network.

Based on the requirements set by NIST regarding cryptographic keys, e.g., a fixed cryptoperiod (i.e., expiration date) or the existence of a key recovery function (NIST 2016), we consider that such a generic approach cannot be applied in an intelligent environment such as a smart grid, since the keys remain static and vulnerable and even though some functional requirements can be met, stricter security requirements cannot be fulfilled. A zero trust design philosophy is required in order to inspire confidence in the validity of the secure keys and certificates.

4. Opportunities

The emergence of technologies such as Blockchain and Artificial Intelligence (AI) has created a new field for research and innovation, while at the same time offering opportunities in the field of smart energy grids. In the following section, we will attempt to identify some of these opportunities and envision how to apply these technologies in order to countermeasure the aforementioned cybersecurity challenges.

4.1 Blockchain Application for Cyber Resiliency

Blockchain is defined as a distributed data base or *digital ledger* that records transactions of value using a cryptographic signature that is inherently resistant to modification (Radziwill 2018). In a move towards a cyber-resilient energy grid, Blockchain could commoditise trust and also potentially support auditable multi-party transactions between energy providers and customers.

The blockchain is the equivalent of a book maintained by a bank, which contains all the accounts and each transaction made. One of the most interesting aspects of blockchains is that they contain the records of every transaction made since the beginning, also known as *genesis block*, by using a peer-to-peer distributed timestamp server which generates computational proof of the chronological order of the transactions (Nakamoto 2008).

The use of blockchain presents numerous potential cybersecurity benefits to the electricity infrastructure:

- **Identity of Things**: As mentioned in Section 3.2.4, identity and access management of the devices in the grid is an issue that needs to be addressed efficiently. The

ownership of a device can change during its lifetime or even be revoked in case a consumer is not consistent with his financial obligations towards the energy provider. Apart from ownership, there are also attributes that each device has, such as manufacturer, type, deployment GPS coordinates etc. Blockchain is able to address these challenges since it can register and provide identity to connected devices along with a set of attributes that can be stored on the blockchain distributed ledger in a fully auditable manner (Khan and Salah 2018).

- **Data integrity**: As per blockchain's design, every transmitted block in the network, thus all data transmitted by the devices in the grid, are cryptographically signed and proofed by the sender. Each node has its own unique public and private key and thereby it is ensured that the data are encrypted and cannot be tampered. Finally, all blocks are recorded and timestamped on the chain and cannot be changed in a later time, therefore ensuring the accountability and the integrity as described in Sections 3.1.4 and 3.1.3 respectively.

- **Securing communications**: The most commonly used network communication protocols, such as HTTP, MQTT and XMPP, are not secure by design and thus have to be wrapped within TLS at the application layer. However, protocols such TLS or IPSec rely on complicated and centralised certification authorities for the management of the keys, mainly through a public key infrastructure (PKI). With blockchain, there is no longer the need to rely on a centralised authority, since each node in the network receives a Universally Unique Identifier (UUID), as soon as it joins the network, and also creates an asymmetric key pair. This allows to simplify the handshake procedure and use light-weight protocols, such as TinyTLS, without handling and exchanging PKI certificates during the initial phase of the connection (Khan and Salah 2018). This way we are able to tackle the challenge described in Section 3.2.4 in an efficient manner without the added overhead of complex PKIs.

4.2 AI and Smart Contracts

Despite the fact that blockchain solutions add a layer of cryptography in communications and digital transactions, in complex IoT environments such smart energy grids, many complex cybersecurity challenges remain. An example is the patch management of the smart meters or their improper configuration. Especially in the first case, the timing between the discovery of a new vulnerability and the deployment of the patch to the affected devices is crucial. In such a scenario, a public repository could be queried periodically in order to check whether a new patch is available. The process could

be performed with a blockchain-based *smart contract*, which would validate the transportation of the correct patch and provide an incentive for updating. Such a smart contract could operate on the basis of device-specific information, mainly model and firmware version of the device. According to this data, the contract would decide on whether an update is necessary and instruct the device to perform the update. In case the device is compromised and refuses to update, its trust score could start to decline and the energy provider would be notified regarding the misbehaving device.

Also, smart contracts could allow customers to directly trade with energy suppliers through autonomous trading agents without having to rely on middle-men. The agreement between the two transacting parties can be recorded in a smart contract which could also handle the automatic payment of the provided service. This way payments can occur automatically through the distributed ledger without the risk of financial data theft from data stored in energy retail supplier's databases (Deloitte 2017). Apart from that, smart contracts and automated transaction execution allows for real time settlement and accurate billing of payments overcome issues experienced in developing countries with delayed payments, debt and large numbers of unbanked population (Andoni et al. 2019).

Whereas the distributed public ledger of blockchain may assist in increasing the trustworthiness, AI-enabled smart contracts could add unique value in the timely response to emerging cyber threats like an emergency response to a naturally occurring weather event or a cyber-physical hybrid attack (Mylrea 2018). That way, some functions of the power grid would become self-healing and resilient.

Additionally, through the combination of AI and blockchain, we could achieve an almost real-time security response to unauthorised attempts to change configurations or network and sensor settings. Anomaly-based intrusion detection systems assisted by Machine Learning (ML), could be an effective method to detect intrusions and attacks, which have not been previously detected. Such a system, combined with the immutability of blockchain, could reduce the overhead of the forensics investigation in case of a security incident, by providing a well-established timeline of events for evidence-analysis.

5.Conclusions

Smart grid is a system composed of various distributed components with the primary goal to intelligently deliver electricity, while at the same time allows the easy integration of new features and metrics in the traditional grid. Cybersecurity in the smart grid is a relatively new area of research and in this paper we presented an initial survey of security requirements and challenges. This was followed by a discussion on opportunities and mitigation techniques based on disruptive technologies such as blockchain and AI. Even though the proposed solutions still remain an uncharted territory in smart grid applications, the advancements in blockchain and AI make them the more attractive technologies thus far in the pursuit of building a secure and resilient smart grid.

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