Internet of Things in Power Industry: Current Scenario of Nepal

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Abstract: - The emerging topic under investigation is the use of Internet of Things (IoT) which has a wide scope of applications, out of which some of the major applications like real-time monitoring, remote sensing, situational awareness and intelligence in electric power systems would be illustrated in this article. In addition, this study is focused on the current status, technical requirements, applications and the scope of IoT in Nepalese market, such as; smart energy system, smart grids, advanced metering infrastructure, centralized and distributed power system through the discussion and the possibilities of implementation in the context of Nepal. It is found that Nepalese power systems also initiating the use of IoT for smart metering, home automation, electrical generation, transmission and distribution system automation, industrial automation, etc.

Key-Words: - IoT, Remote Control, PLC, SCADA, Automation, Control System

1 Introduction

Nepal is a developing country where the power supply is highly dependent on hydroelectric sources [1] [2]. There are different sizes of hydropower plants installed throughout the country and the size is based on the geographical location, availability of water and plant feasibility, distance from load centre, etc. Power plants require continuous monitoring and inspection at frequent intervals and thus real-time monitoring and control system is the most important part of the power plants [3] [4]. The faults identification, troubleshooting and quick re-start of the system are the major considerations for reliable power plants and Internet of Things (IoT) creates an interconnection between the physical world of things with the virtual world of information [5] [6]. In this study, the current scenario of automation technologies, scopes, and impacts, etc. in power systems are discussed. It is mainly focused on the current practices and implementation of IoT in the power sectors of Nepal. Also, the impacts of IoT in the distributed generation systems, medium and large power stations along with the distribution networks have been discussed.

The main objective of this study is to investigate the current scenario, technical viability, requirement, application and the scope of IoT in the Nepalese power industry. In this study, first, we introduced the basic background of the Nepalese power market with their challenges. In the second section, the overview of the IoT system is discussed. The third section discusses the policies and strategies of IoT implementation by the power sector. The fourth section discusses the socio-economic impacts of IoT based control system in new and upgrading the existing system into IoT. The fifth section presents technical challenges and complexities. Finally, in the sixth section, the conclusions and discussions have been drawn.

2 Overview of the System

The interest of process automation evolves from minimizing human interference in the systems to avoid health hazards and to increase productivity. Automation in the manufacturing industry has evolved from the use of basic hydraulic and pneumatic systems to today's modern robots [7] [8]. The benefits of automation include increased productivity and quality, improved accuracy, saving material costs and energy [9]. Going through the technological transformations from the past, the wireless-based automation system is being adopted in the different types of system and the use of IoT in them is to ease their operation.

Radio Frequency Identification (RFID) can be considered as the foundational technology for the IoT which was commercially used from the 1980s in industrial applications [9]. The microchips in RFID tags send the information to the control station through the communication networks. RFID technology has been widely used in various applications since 1980 [9] [10]. In the early 1990s, the evolution of Wireless Sensor Networks (WSNs) introduced the new era of sensing technology which

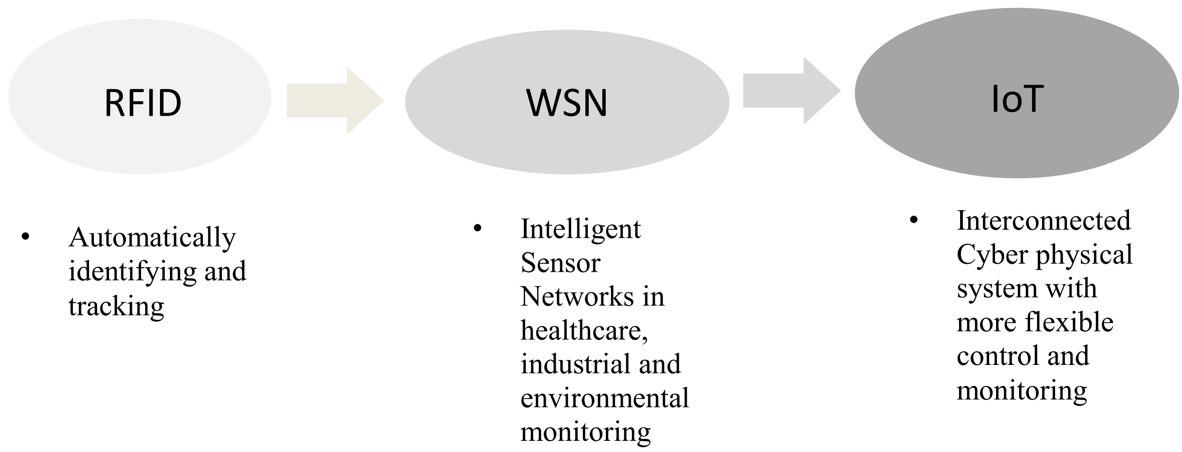

Fig. 1 Historical Development of Automation Technology

was mostly used in healthcare, traffic monitoring, industrial and environmental monitoring and now they are been integrated with internet and termed as a cyber-physical system or the IoT [4] [11].

The use of internet in the control systems is being introduced for the added benefits of remote sensing, distance control, easier data acquisition systems and flexibility of the automation system adopted in the industries as well as in power and energy systems [12] [13]. IoT is being a topic with a wide scope and emerging technologies, it can be implemented in various systems to make the system operation easier and less human intervention in the automated control system with global networking infrastructure. The concept of micro-grids, smart grids, advanced metering systems, centralized load dispatch and control systems, distribution system automation etc. uses any of the features of IoT. In the context of Nepal, implementation of IoT in power system automation and control is still under research and some of the implementations of such projects can be seen as pilot projects of the utility companies and the local governments.

The architecture of IoT is basically divided into 4 layers. First layer includes sensors and actuators which are integrated into hardware to collect the information from them. After that, networking layer for the transmission of collected data from sensors to control units and control units to the actuators. To access the services based on user needs and to interact with the control units service layer and interface layer are defined.

Table 1. Design Considerations for IoT in industries [9] [14]

Goals	Explanation
Energy	Operational limitations for limited power supply
Latency	The time required for information exchange
Throughput	A maximum amount of data that can be transported through the system
Scalability	Number of maximum supported devices
Topology	The communication chain, which communicates to which node
Security and Safety	The level of security in the system

2.1 Smart Energy Districts

In the last decade, the interest for distributed generation (DG) has been induced drastically due to technological innovations and a changing economic and regulatory environment [15]. Private small plants, especially from non-dispatchable renewable energy sources, are directly connected to the grid. Power Cloud injects smartness into the management of an energy district so as to improve the global energy efficiency [14]. The article [16] proposes IoT solution for energy districts which aims the energy exchange within the various distributed generation plants and local energy storage system to the distribution grid with the goal of improving the energy efficiency and reducing the costs.

2.2 Smart Grids

Smart grid technologies were emerged as the consecutive development of electronic control, metering and monitoring and the National Academy of Engineering in the USA has also quoted the electricity grid as one of the major achievements of the mankind in the 20th century [4] [17]. The smart grid establishes two-way interaction between the consumer and the utility service company where electricity and the information can be exchanged. It is a network of communication, controls, computers, automation, and new technologies and tools working together to make the grid more efficient, more reliable, more secure which also improves the speed of fault detection and allow self-healing of the network by possible rerouting and switching into another healthy source without the intervention of technicians. This will improve the reliability of electric supply, and reduces vulnerability to natural disasters or attack [18].

The smart grid can be viewed as the latest upgrade of the pre-existing electrical power systems which allows the dynamic gateways for distributed generations and storages, and smart optimization of energy usage [4]. Smart grids are also referred as intelligent grid or future grid [19] and according to the Energy Independence and Security Act of 2007 [20], must include the basic features like fault tolerant by resisting attacks, self-healing capacity, dynamic optimization, improved reliability, power quality, incorporation of demand response and integration of distributed energy sources. In the context of Nepal, there are no existing smart grids but there have been a lot of infrastructure developments which help to introduce the existing grid systems into the smart grid [21].

In figure 2, the layout of the smart grid is presented which features the end to end communication of the power system to ensure better performance and reliability. All types of generating stations, transmitting and distributing substations, end consumers and the control stations are linked by the internet protocol, which exchanges the information to and from those units. If there is an increase in demand, the generating station increases the active generating units within them and the distributed generating stations which are isolated during low demands are also activated to meet the energy demands. When there are any faults in the certain sections, those are isolated automatically and possible rerouting will be accomplished to ensure the power continuity. To save the cost of energy, the scheduling of usage of electrical loads like electric vehicle charging, operating washing machines, etc. can be automatically scheduled to operate in the off-peak hours.

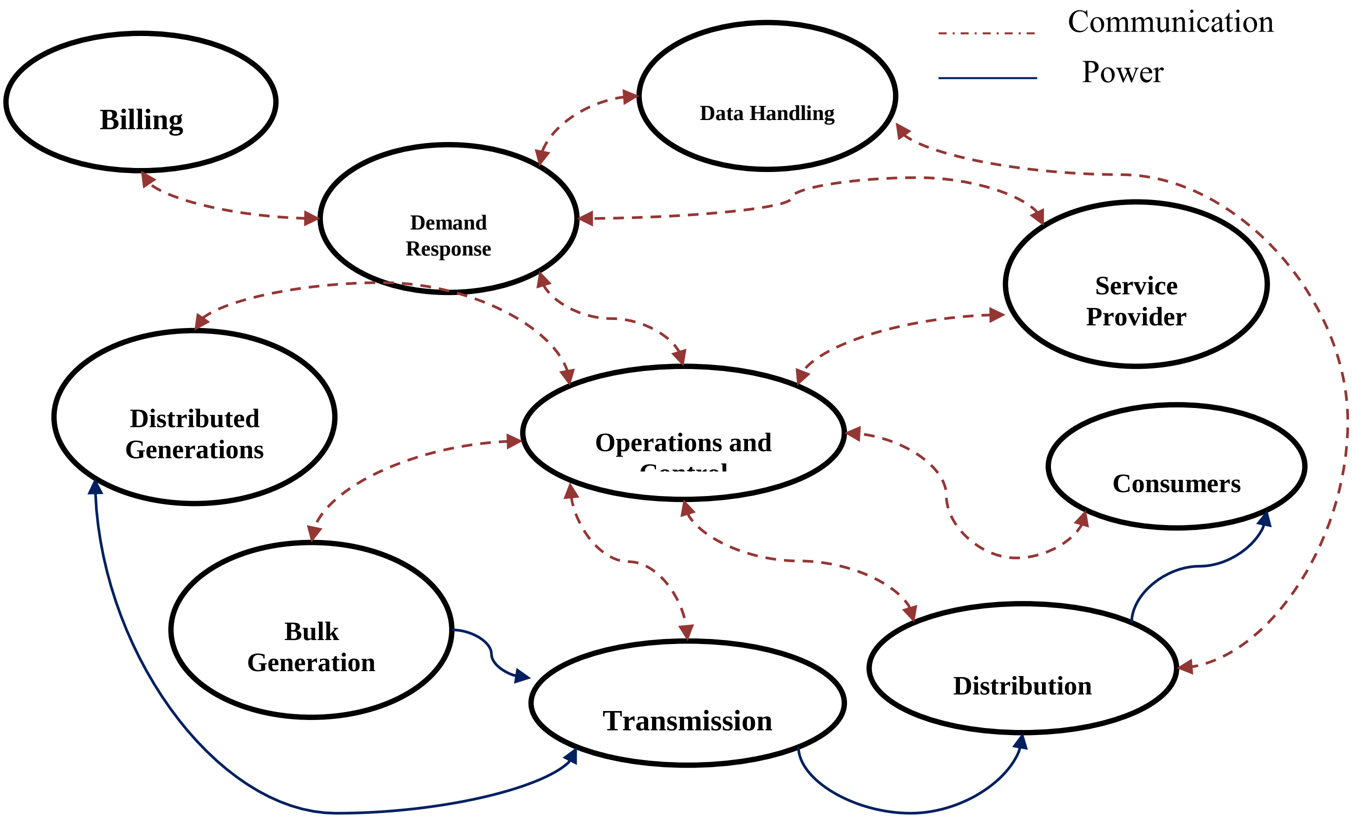

Fig. 2 Typical Layout of Smart Grid

2.3 Smart Energy Meters

The development of smart meters is the advancement of the previously in use electromechanical energy meters. The electromechanical meters operate according to the number of revolutions of an electrically conductive metallic disc rotating with proportional to the power consumed [22], while advanced metering infrastructure or smart meters enables two way communication between supplier and consumer to ensure the reliable power supply by minimizing the outage and losses, optimize the energy costs along with remote monitoring and control facility [23].

Smart energy meters are used to record energy consumption hourly or more frequently and reported at least daily to the utility service provider [24]. Smart metering infrastructure also plays a vital role in other applications like detection of electricity theft, improved system security, load dispatch and control along with development of smart urban cities [2] [24].

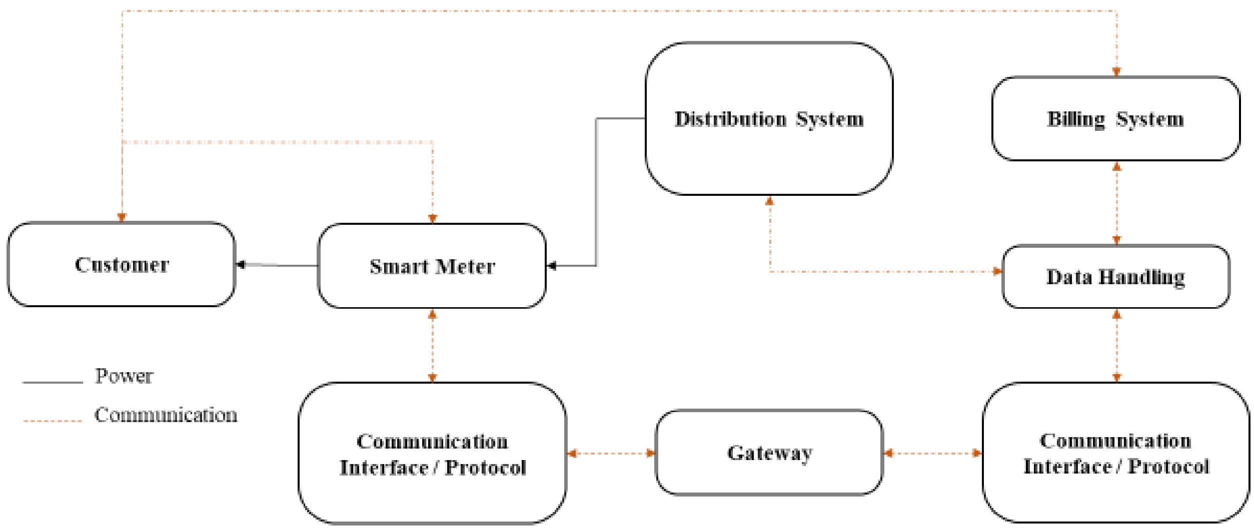

Fig. 3 Layout of Smart Meters

2.4 Centralized and distributed power system

NEA was working in integrating the distribution grids into direct observation of Load Dispatch Centre (LDC) of every feeder to keep the operation of the Integrated Nepal Power System (INPS) on the right track through the use of computer-based Supervisory Control and Data Acquisition (SCADA) system. The availability of real-time data has improved the load forecasting and fast restoration of the power system in during black-outs, which reduces the revenue loss.

As a good impact of the system upgrade and centralized load dispatch system reduced the number of complete systems failures to 26 as compared to 28 in the previous year, and the subsequent complete power outage time has been reduced to 430 minutes as compared to 1053 minutes (465 minutes during earthquake) in the previous year [2].

2.5 Distribution system automation

The electric power distribution system is an important part of electrical power systems in the delivery of electricity to consumers. For the flexible control of distribution systems, distribution system automation (DSA) has played a vital role which can enhance efficiency, reliability, and quality of electric supply. Distribution Automation Systems have been defined by the Institute of Electrical and Electronic Engineers (IEEE) as systems that enable an electric utility to monitor, coordinate, and operate distribution components in a real-time mode from remote locations [25]. For making distribution automation more intelligent, efficient and cost-effective worldwide research and development are focused in the areas of revolution of communication technologies and application of IEC 61850 protocol in the distribution automation [26]. Until these days, DSA technology is established not just as remote operation and control of substation and feeders, but it is transforming into a self-healing power system that responds immediately to real-time appropriate actions.

NEA has also put forward the plan to prepare GIS-based inventory to track its poles, transformers, cables, consumers' connections to each transformer to know all the data & their existences in the distribution system as a pathway to development of DSA. This system would also help the system engineers to get actual data of poles, transformers, and consumers' capacity and also to balance the transformer's load as per connection to the consumer [21]. The additional benefits of this system would be a quick assessment of fault detection and localization which supports the No-light/Customer Care section of NEA to troubleshoot the faults in a quick and easier way.

2.6 IoT in Process Industries

The use of IoT has been adopted widely in the field of Industrial automation in developed countries. Automatic Guided Vehicles (AGVs) are used for the purpose of unmanned transportation especially for moving goods from one location to another with self-loading and unloading capacity. AVG follows the lines in the floor or uses vision cameras, radio waves or laser for navigation [27]. AGVs are also used in cleaning, assistance to deliver peoples, etc. and they can be centrally controlled from the cloud-based server [28]. As the technological revolution in the industrial automation systems, industry 4.0 has been introduced as the generation of robotic industrial automation system which is also termed as the cyber-physical system or the IoT [29].

3 Policies and Strategies

NEA governs all the generation, transmission and distribution of power system in Nepal. After the successful ending of prolonged load-shedding, NEA has now become able to focus to upgrade the grid and distribution substations for increasing their capacities to handle the increasing energy demands [2].

Recently, NEA introduced Kathmandu Valley Smart Metering Project (KVSMP) as a component of power transmission and distribution efficiency enhancement project. KVSMP is funded by the Government of Nepal and Asian Development Bank with the strategy to implement Advance Metering Infrastructure (AMI) [30] as a reform in the distribution sector of NEA [21]. NEA aims to install AMI system initially to 90,000 consumers as a pilot project within Kathmandu valley within the end of 2021. This project aims to a reduction in meter reading costs and better system management, facilitate online billing and also studying the feasibility of initiating a time of use-based tariffs [2].

Substation Automation System (SAS) is another project under construction which is implemented into all of the substations which are now being upgraded to higher capacities and added SCADA integrations with a system upgrade in their LDC [2]. The benefits of SAS are Substation control by the remote terminal, access to real-time data enhances management, minimizes outages, improves productivity, easier fault detection for distribution systems, security with multiple access levels [2].

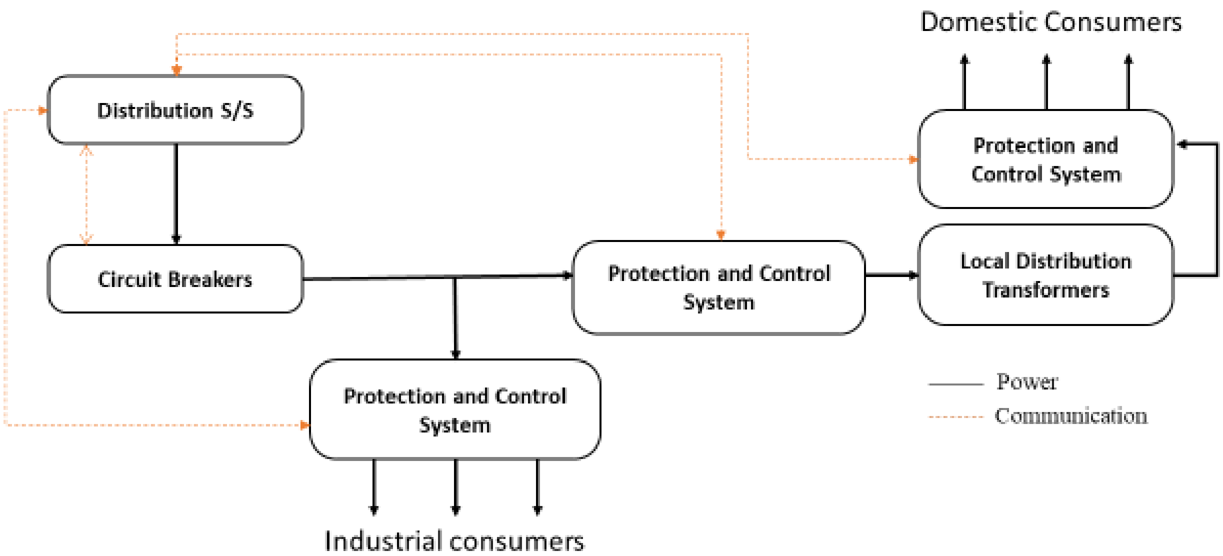

Fig. 3 Layout of Smart Meters

In figure 5, the proposed scheme of IoT based smart Utility billing system is proposed for the implementation as KVSMP. This system should have an expandable capacity of interconnecting up-to 1.2 billion customers even the first piloting is being done for 90,000 customers in the first phase. This system is proposed to be able to communicate real-time data from service provider to customers and vice versa using IoTs with a feature of remote control and online payment gateways.

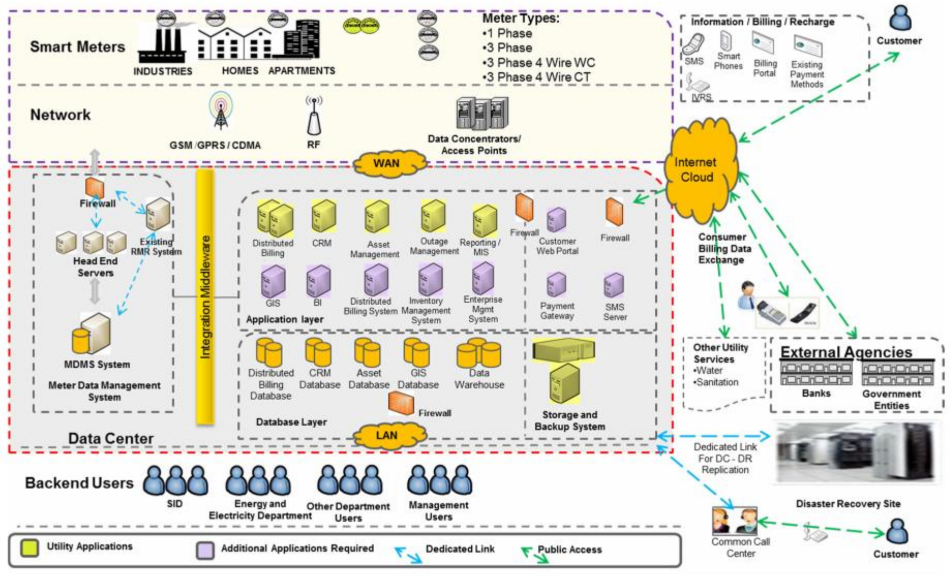

Figure 5. Smart Utility Meter Architecture with IoT [21]

4 Socio-economic impact and scope of the system

The implementation of IoT based systems in any existing plants may be costly at the time of installation as there is required to replace old components due to incompatibility with the newer systems. [31]. The use of IoT based systems in such applications saves the time and money as well. People can know their bus schedule through their mobile applications. People are now become able to track their health conditions and get alarm if there are any abnormalities or the automatically inform the healthcare units for emergency supports. While driving in the highway, people can get information about the traffic conditions in advance to select the alternative routes in case of traffic congestions or road blocks due to any reason. The public transportation service providers can monitor and control their fleets through IoT. In Industries, the AGVs are operated by IoT, which helps in the movement of physical objects without human interventions.

Power grid are now able to handle proper scheduling of powerplants operation according to the demand response, smart meters allow the utility companies to charge separate rates for energy consumption based on the time of day and the season [18]. Based on the time of day billing, small to large consumers get equally benefited and the cost of energy would be more relevant.

Every application of IoT is directly linked with the welfare of the society and the better life of the people. It also, has created the better job opportunities in installation and maintenance of the system too.

5 Technical requirements and challenges

5.1 Sensing

The sensors used in the automation systems should be able to integrate real time data with situational intelligence, high-accuracy, added more security layers to meet the requirements for real time operation through cloud computing and IoT. For implementation of precise automation system, real-time sensing devices are needed [32]. Sensors selection would address the economic aspects as well as the technical aspects of the system. The cost of sensors would vary based on the required accuracy level, working environmental conditions, etc. To generate high-accuracy information in existing old systems, arrays of low accuracy sensor modules with subsequent data fusion can also be implemented [33, 34].

5.2 Power management

The major considerations for the remote sensing using IoT devices is the energy used by the sensor networks and the nodes. Specially, for collecting data for environmental monitoring, disaster early warning systems, etc. require to operate with optimal power as the source of power may be only battery or solar photovoltaic cells [8].

5.3 Connectivity

The large amount of data transfer in the same time through the same network may cause delay, data loses and other communication issues. The balanced operation of the sensor node includes the proper communication protocols to minimize the data loss and jamming during information exchange in between. These should be addressed while choosing the communication protocol and the connectivity for the system [8, 13].

5.4 Security

The security issue in the cloud-based system should be addressed properly to ensure the data loss, vulnerable attacks and system misuse [8, 13]. The enhanced security features in the network also improves the communication, computation and hence better performance of the entire network [35]. The goal of security in the wireless networks should integrate prevention, detection and reaction. It should be able to prevent the system from unusual attacks and disturbances, should be able to detect malicious activities and take an immediate reaction against them to provide confidentiality, authentication, anonymity, integrity and availability to wireless sensor nodes [36].

5.5 Scalability

By increasing the number of interconnected physical objects, the scalability capacity of the IoT based system must be flexible to meet the expanded demands [13]. There are many types of scalability techniques to address the requirements of the system. The scalability should be considered more for the highly expandable networks like smart metering, IoT based public transportations, etc.

6 Conclusions and Discussion

As seen through various IoT based systems, the inter-link between the physical objects through internet or the IoT has explicitly played vital role in the upgrade or upliftment of the existing systems and procedures. IoT has seen to be enhancing the SCADA systems in the automation sector by introducing the remote sensing and control facilities. Due to the interlinkage of physical objects like public transportation, power grid operations and monitoring, better health care by tracking the body vitals and frequently reporting, coordination of live traffic, tracking of assets, interconnected fleet management, self-driving vehicles like AGVs through the internet has improved the lifestyle as well as the socio-economic status of the people around the world. The use of IoT in different sectors has helped to reduce the people to work in hazardous environment by using the automated systems and increased the productivity too.

IoT is now emerged as universal paradigm which can drastically transform any industries equipped with sensing, identification, remote sensing, automated control capabilities. The German industry 4.0, has technological base as IoT, which basically has the theme of robotic process control through less human interventions in industries which has very huge impact in the global market.

Some of the existing industries are seen in the phase of upgrading into IoT based systems to benefit from the reliable advanced technology. In the context of Nepal, NEA is replacing the conventional electromechanical energy meters with IoT based advanced meters to ensure the better service delivery as well as to save the cost in meter reading by door to door and revenue collections through the various counters. The increased demand of electricity induces the need of intelligent technologies of efficient and secure operation and control of the power grids. The time varying sources of energy and integrated dynamic loads demands the operation of smart grids in Nepal. As the pathway for smart grids, the infrastructures like distribution automation system and smart metering system are now being implemented.

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