KATHMANDU UNIVERSITY

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DEPARTMENT OF COMPUTER SCIENCE AND ENGINEERING

DISSERTATION

INFRASTRUCTURE ANALYSIS AND IOT FRAMEWORK DEVELOPMENT FOR SMART CITY IN NEPAL

In Partial Fulfillment of the Requirements for the Doctorate of Philosophy (PhD) Degree in Computer Science & Engineering

by

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ABSTRACT

In search of employment and improved lifestyles people move to cities. Due to this type of shift it becomes difficult to provide services to the citizens and hence the cities need to become efficient to maintain the services to the surging population. Sooner or later the concept of smart city will become norm for the cities and start using Internet of Things (IoT) devices which contains the sensors to receive the data and these sensors are connected to the microcontrollers to collect, transmit and analyze the data. The collected data are then used to enhance the existing infrastructure and provide efficient public services and many more.

IoT framework developed in this study is generic and this study is concentrated taking water supply management into consideration. Automating the process of doing things in IoT systems begins with the management of fundamental needs like air, water and electricity. Used and leakage amount of water can be monitored and controlled remotely using an application of an IoT system. Injecting IoT in water supply management helps in online meter reading, online monitoring of water usage and leakage condition of a single house and then of municipalities and eventually of a country. IoT system installed in houses consists of an embedded system that contains microcontroller, sensors and coding in the microcontroller. The IoT system also uses the mathematical model that has been developed empirically to compute the usage and leakage of water of a country. The developed framework can be applied to other sectors as well.

The infrastructure analysis has been carried out followed by the observation and interview taken with key people of Nepal Government. Altogether 23 interviews as a part of qualitative research were conducted to find out the answer to know where the problem is to establish efficient smart city. The result of the interview depicted that, lack of political initiation and commitment is the major problem, the second problem has been seen as low computer literacy, similarly lack of Public Private Partnership (PPPs) in establishing e-Government system, reluctance in technological usage and advancement are the major hindrances to develop smart city. Knowledge regarding Internet of Things (IoT), low awareness of about e-Government system is found to be other barriers to develop the smart city. This research has focused on water supply sector to realize the developed IoT framework.

Keywords: IoT; Future internet; Smart city; WSN; Embedded devices.

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ABBREVIATIONS

IoT: Internet of Things

GoN: Government of Nepal

NTA: Nepal Telecommunication Authority

NITC: National Information Technology Center

WSN: Wireless Sensor Network

A2D: Analog to Digital

ADC: Analog to Digital Converter

e-Govt: Electronic Government

ICT: Information Communication Technology

IDI: ICT Development Index

QoS: Quality of Service

IP: Internet Protocol

IPV4: Internet Protocol Version 4

IPV6: Internet Protocol Version 6

AES: Advanced Encryption Standard

DES: Data Encryption Standard

NPB: National Project Bank

BIS: Bureau of Indian Standard

MEMS: Micro Electro Mechanical Systems

RFID: Radio Frequency Identifiers

NFC: Near Field Communications

KUKL :Kathmandu Upatyaka Khanepani Limited

HCI: Human Computer Intervention

SOC: System on Chip

ISP: Internet Service Providers

DNF: Digital Nepal Framework

DMA: District Metered Area

CONTENTS

CHAPTER 1
INTRODUCTION

1.1 Background

Internet of Things is a smart technology that uses appropriate analytics and secure connection between machines (hence, also referred to as machine-to-machine technology) to turn data into usable information for individuals and organizations. The technology uses hybrid computers for computation and stores the obtained information in mechanisms, such as BigData technologies and cloud stack.(Holguin-Veras et al., 2018).

So as to uplift the lifestyle of the residents and the cost of their buildings, building managers throughout the world, especially in smart cities, are constantly seeking IoT devices to incorporate them in their creations. According to a recent survey by Daintree Networks in the United States, nearly 60% building managers are acquainted with IoT while 43% think, in the coming 2 or 3 years, their line of work would be heavily influenced by IoT (Lima et al., 2018). An instance of implementation can be in the area of lighting. Since LED bulbs save large amounts of energy as well as money. The domain of elevators can equally be the next big thing for IoT. A study by IBM in 2010 showed that people of New York City spent an average of 22.5 years waiting for elevators. This has led to research by various clients, among which, the one by Allied Market Research indicated that the market for smart elevators might double in just 5 years' time from 2015 – from twelve billion dollars to twenty-three billion dollars.(Lima et al., 2018). Table 1.1 shows the key themes related to smart city. The entities mentioned in Table 1.1 are important factors to take into consideration for developing smart cities.

Smart grids are arguably the best examples of smart architecture and infrastructure as they greatly aid resource conservation. By 2020, the European Commission believes 72% of the residents of the European Union to have smart electricity meters placed in their homes, with 40% having a smart gas meter. For example, in Amsterdam, home energy storage units and solar panels are being offered to residents who are linked to the city's smart grid. Since, during the off-peak hours, the batteries store energies, it can be used during the peak hours so as to reduce stress on the main grid. (Lima et al., 2018).

The Internet of Things (IoT) is a fast expanding network of interconnected devices that gather and share data via embedded sensors. Such a network can be a connection including cars, refrigerators, heaters, and other devices. Internet of Things (IoT) might be defined as a network of interconnected digital and mechanical computing devices,

Table 1.1: Key themes related to smart city (Wijs et al., 2017)

Smart Mobility	Smart Economy	Smart Living
• Improved Accessibility • Safe Transportation • More efficient and intelligent transportation systems • Leveraging networks for efficient movement of vehicles, people, and goods, to reduce gridlock • New 'social' attitudes such as car sharing, car pooling, and services like car-bike combinations	• Regional/global competitiveness • Entrepreneurship and innovation Momentum • High Levels of Productivity • Broadband access for all citizens and business opportunities independent of location • Helping maintain population in rural areas • Electronic business processes like e-banking, e-shopping,	• Better Quality of Life • Social Aspects- Education, healthcare, public safety, Housing • Access to high-quality healthcare services (including e-health or remote healthcare monitoring), electronic health record management • Home automation, smart building services • Access to social services of all kinds
Smart Governance	**Smart People**	**Smart Environment**
• Hands-on resolution Making • Using Communal services • Clearness • Self governing processes and enclosure • Interoperable governmental organizations and • Enhancement of services to citizens	• Creative and literate Citizens • Making use of ICT in the available services • Reducing the digital divide by delivering consistent education in urban and rural areas • Promoting e-education (remote learning and collaboration) to make citizens informed	• Using green energy • Monitoring the level of pollution • Use and reuse of materials and decreasing the consumption of energy by using recent and novel technology incorporating ICT

other objects, and even animals or humans, all with unique IDs. Such a network has the capacity to transfer data among itself without the need for any external impulse. A node of such a network might be a human having a pacemaker, another animal in a farm housing a biochip transponder, a vehicle with systems and sensors so as to show an alert when there is a malfunction in any of its parts. In a nutshell, it can be any "body" (man made or natural) that can be assigned a unique IP address and connected in a "network". In recent years, we have seen substantial development in wireless technologies. The internet has evolved a lot and so have other technologies like

Micro-Electromechanical Systems (MEMS). This has led to the seamless integration of the domains like Operational Technologies (OT) and Information Technology (IT). This has allowed for the analysis of the unstructured data, generated by machines, which is bound to further the improvement in time being.

In recent days, computers, and thus the Internet, rely almost entirely on people for information. Almost all of the 50 petabytes (1 petabyte is 1,024 terabytes) of data available on the Internet were first captured and created by human beings by typing, pressing a record button, taking digital photos or scanning bar codes. (Adegboyega Ojo and Curry, 2016).

The problem is that people have limited time, attention, and accuracy which shows people are not good at capturing data about things in the real world. If there were a computer that knew everything they had to know about things using the data they had gathered. Without any help from human beings, this could help to track and count everything and waste, loss, and cost can be significantly reduced. (Adegboyega Ojo and Curry, 2016). We could find out when things need to be replaced, repaired, or recalled, and whether they were new or old. (Adegboyega Ojo and Curry, 2016).

The significant increase in address space brought about by IPv6 is an important factor in the development of the Internet of Things. According to Steve Leibson, who identifies himself as "occasional docent at the Computer History Museum," the address space expansion means that we could "assign an IPV6 address to every atom on the surface of the earth, and still have enough addresses left to do another 100+ earths." (Rathore et al., 2016a). In other words, humans can easily assign IP addresses to any "thing" on the planet. Increase in the number of smart nodes and the amount of upstream data they generate is expected to raise new concerns about data protection, data sovereignty, and security (Rathore et al., 2016a). Practical applications of IoT technology are found today in many industries, such as precision agriculture, building management, healthcare, energy, and transportation. Although the concept wasn't named until 1999, the Internet of Things has been in development for decades. For example, the first internet device was a cola machine at Carnegie Mellon University in the early 1980s.

The technology roadmap of IoT as shown in Figure 1.1 depicts the prediction done in 2005, "By 2020 fusion between software agents and advanced sensor will be done". Those were the days when embedded system developers used a microcontroller chip like 8051 and 8052. The 8051 and 8052 family microcontroller is shown in Figure 1.2 and Figure 1.3. The major problem for the programmer to burn the hex code in the chip was complex. After some years AVR microcontroller was developed which minimized the discrepancy of 8051 and 8052 family by introducing a simple program loader.AVR microcontroller chip as shown in Figure 1.3 however, did not have proper forum and module-based programming was not facilitated. Arduino board as shown in Figure 1.4 was developed, which has a forum for solving queries, so that people around the world could communicate about the development of code and share the problem they faced. Arduino has many built-in features, but to connect to internet, it required arduino ethernet board separately.

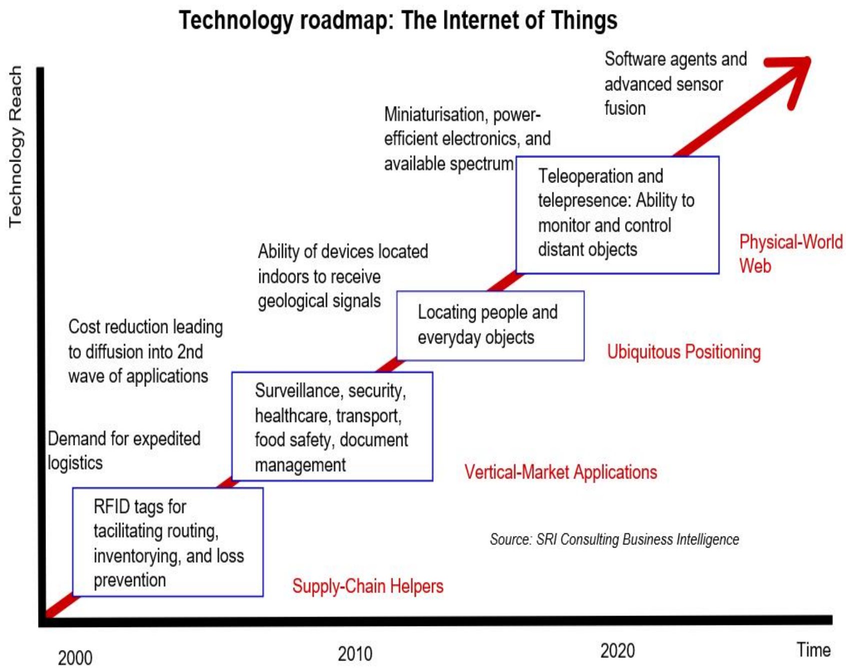


Figure 1.1: Technology roadmap: The Internet of Things (Patton, 2005)

Figure 1.2: 8051 and 8052 family microcontrollers (Prachi Dukale, 2019)

Recently Raspberry-Pi board as shown in Figure 1.5 has been developed, which has the facility to interface the sensors to the microcontroller and connect/ transfer data over

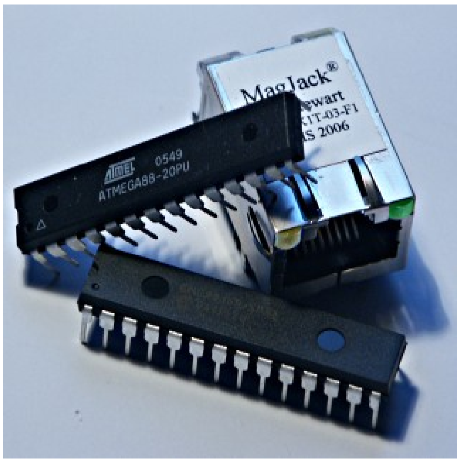


Figure 1.3: AVR family microcontrollers (Cubero, 2015)

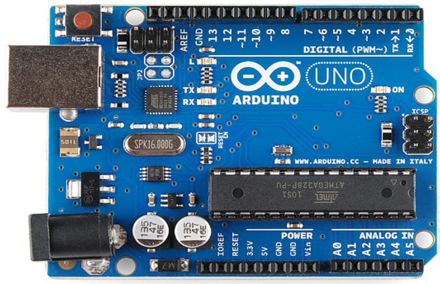


Figure 1.4: Arduino microcontroller board (Leon et al., 2017)

the internet. After the advent of Raspberry- Pi, IoT is pronounced more these days, and the fact is that IoT can be the heart of smart city.

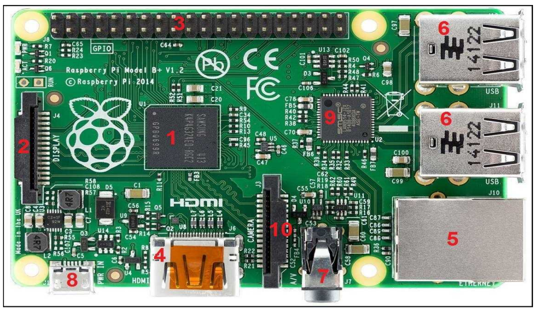


Figure 1.5: Raspberry Pi board (Leon et al., 2017)

One of the preliminary steps to establish smart city is analyzing the existing infrastructure. Some cities like Dubai, Malta, Singapore and Kochi (India) are recently named as smart cities (Al-Hader and RODZI (2009)). Using the concepts of automation, communication technologies and internet of things, smart cities can be constructed. The main objective of creating the smart city is to minimize and manage the consumption of power and operational resources thereby reducing the overall operational cost. Sectors that are either education sector or governmental sector or industrial sector are coming out with the innovative ideas, and most of them are incorporating the use of internet services. Sustainable growth in economy by using modern ICT infrastructure and investments made in human and social capital remain traditional, and this is what a smart city means. This meant to enhance the quality of life of citizens by wisely managing the available natural resources.

Sustainable and smart cities can be established by using the ICT technologies and emerging trends of Internet of Things (IoT) that enhance the life standards of the people living around. The quality of life increases by providing efficient services to the citizens. IoT enabled services also ensure the present and future needs in regard to the social, economic and environmental aspects.

The inter-linkage between the physical, business, ICT and social infrastructure defines the intelligence of the city, and it is depicted in Figure 1.6. All the infrastructures play a significant role in forming a intelligent city. If any one of these four infrastructures is weak, it directly affects the intelligence of city. Analysis of these infrastructures is vital to inject IoT in available systems. The IT and cyber infrastructure from security point of view has special interest regarding the confidentiality, availability, integrity and accountability for ever because intruders are always seeking for security vulnerabilities to enter into the systems. The existing standards regarding safety of cyber infrastructures and IT are not enough to protect the system, and it is the main reason for the vulnerabilities to exist.

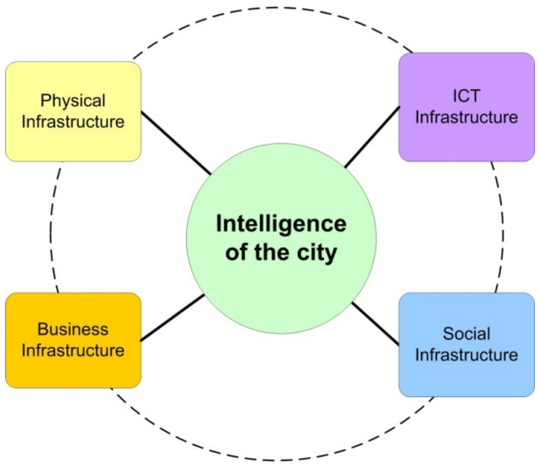


Figure 1.6: Inter-linkage between infrastructures of a city

Figure 1.7 displays the barriers to the implementation of smart city. Before making the action plan regarding the implementation of smart city, these critical barriers should be taken into consideration.

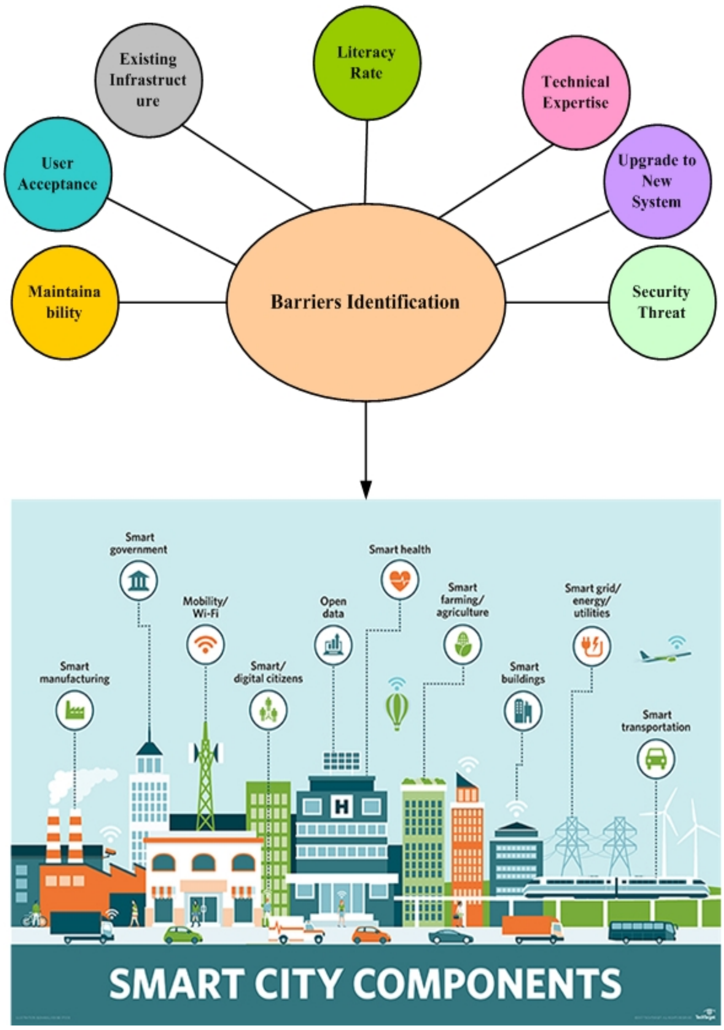


Figure 1.7: Barriers for smart city implementation yoSoyTono (2018)

The Internet of Things (IoT) is a contemporary area that is enticing many researchers. The importance of IoT explains the wide scope of IoT. However, it ignores the quality and capability factors of IoT which are of high importance for creating value to the public, particularly in the sense of smart government, and that is a major objective of IoT. IoT can be understood as the ability of things to behave on their own, and share data and available resources by acting and reacting whenever there is a change in the existing environment by the linkage of wide-ranging grids or networks where these objects are connected. The usage of IoT is exponentially growing. Recently, the use of IoT networks with many associated devices in them has grown dramatically, and this has resulted in increased expectations among different organizations to create and deliver value to the public. The pervasiveness of the internet has caused significant changes in people's life. Likewise, the IoT can create a powerful impression on society in coming years. Therefore, the IoT is recognized as the future generation of the internet. IoT can not only save available resources and increase the effectiveness and efficiency of a system overall but can also generate benefit to both public and private sectors. An IoT framework plays an important role in transforming society because its usage comforts and benefits citizens in different ways, and improves their lifestyles.

1.2 Problem Statement

Some developed countries have started understanding that implementing the concept of IoT at the core of their development plans is the way towards enabling smart cities. However, it is not possible to implement IoT without a proper framework and operating procedure. In terms of technological aspects in incorporating IoT, an authentic framework and well defined operating procedure is a must. The technological aspect of IoT implementation deals with features like, interfacing the sensors, generation of data, analysis of data, feeding the data to a data center and deriving the advantage from data residing in the data center. In Nepal, access to the internet has been increasing exponentially. Nevertheless, the advantages of automation with the usage of IoT in transforming the lives of people have not been realized yet.

People are yet to understand that the implementation of IoT could automate most of their manual work and ease day-to-day activities. On the other hand, Nepal lacks the basic infrastructures such as data centres, IT literacy, ISPs, and reliable software companies. This could be one of the reasons that none of the developmental programs in Nepal has introduced IoT frameworks. Thus, the development of basic infrastructures required for IoT and incorporation of IoT in development planning must go hand-in-hand. Private companies would be more interested to invest in infrastructures and IoT frameworks if the government considers using IoT in the development programs.

1.3 Motivation

It is more than a decade having been involved in developing embedded system projects, and with the emergence of the modules like Raspberry-Pi, IoT is getting special interest in recent days, but, due to the lack of authentic framework the expected pace of injecting IoT in several systems is not taking place. Therefore, it is important to construct a comprehensive IoT framework that is essential to develop smart city. By reviewing the literature, it is found that there is lack of authentic IoT framework. The paper entitled " Internet of Things for Smart Cities" in IEEE internet of thing journal has encouraged and motivated to carry out this research work.

1.4 Research Questions

The research questions formulated for this study are as follows:

1. What is the status of available Information Communication Technology (ICT) infrastructure to implement smart city in Nepal?
2. How does IoT framework contribute to smart city initiation by applying it in water supply sector of Nepal?
3. What are the implementation barriers and challenges to smart city in Nepal?
4. How is IoT framework developed for several developmental sectors?

1.5 Objectives

The objectives of this study are:

1. To develop a generic IoT framework to build smart city in Nepal,
2. To perform infrastructure analysis for implementing the concept of smart cities in Nepal,
3. To develop mathematical model and realize IoT framework for water supply sector, and
4. To identify the barriers and challenges to implement smart city in Nepal.

1.6 Structure of Thesis

The thesis comprises of seven chapters. Chapter One shows the problem scenarios, motivation of the study, research questions, and research objectives.

Chapter Two is a review of literature within the field of study of internet of things and smart city. This chapter contains previous research work related to similar studies. The second chapter also includes a comparison of different IoT frameworks.

Chapter Three offers a methodology of research and the steps carried out to conduct the research. This chapter also includes research approach, tools, experiment as well as samples required to conducting the interview.

Chapter Four presents the generalized IoT framework developed from the study and comparison of nineteen IoT frameworks. The details of the entities that are included in the framework are explained in this chapter.

Chapter Five gives results and analysis, and it contains explanations about the experiments carried out in the study, and also enlists the details of mathematical models developed empirically in this research work. This chapter also includes findings of the study. The findings are categorized as; findings from an experiment, findings from observation / survey, and findings from interview.

Chapter Six is discussion, and it includes the discussions regarding the framework and interview carried out in this study. This chapter also includes the verification, validation, and reliability of an outcome of this research task. The total uncertainty of the developed IoT framework is calculated, and compared with the outcomes of similar studies.

Finally, in the seventh chapter, contribution, novelty, limitations, and future steps of this study have been summarized. Also, recommendations are provided to the concerned authorities in this chapter.

CHAPTER 2
LITERATURE REVIEW

2.1 Smart cities around the globe

Smart City models are defined by six primary features based on City Science: smart economy, smart mobility, smart governance, smart environment, smart living, and smart people. The transportation network, as an integral component of smart cities, plays a crucial role in addressing urbanization, competitiveness, sustainability, and mobility challenges. Due to increasing population and travel demands, and century-old transportation infrastructure, most metropolitan areas are facing significant transportation-related challenges, including excessive recurrent and non-recurrent congestion, increased accident risk, severe traffic-related air pollution, critical infrastructure protection, and unsustainable energy consumption(Wirtz et al., 2018a).

Developing improved operation and management strategies is critical to improving city-scale transportation system operations which are goals of smart city. Smart city will considerably improve our scientific understanding of data-driven urban traffic system design, operation, and planning, control, management, and sensor technologies, as well as recent developments in data analytics and urban experimentation.(Wirtz et al., 2018a).

A smart city incorporates information and communication technologies, along with Internet of Things (IoT) solutions for costs and resource consumption reduction, performance enhancement, and effective connection and engagement with its citizens. This massive and semi-structured collection of city and citizen data opens up a slew of possibilities for smart city applications based on big data technologies (Gubbi et al., 2012).

The federal government of the United States of America (USA) has been playing significant role in supporting smart-building applications. General Services Administration's (GSA) are working to construct Smart-Buildings for the federal government to fulfill the aim of technologizing the federal government buildings by connecting recent technologies that make them more energy-efficient (Atkinson and Bennett, 2021). Fortuitously, the world now has witnessed the germination of IoT. Though IoT was pronounced in the early times of 2000, it has now grabbed abundant attention and interest in almost all areas that include scientific and industrial grounds like smart-home, industry, entertainment, robotics, agriculture, healthcare, and transportation (Ray et al., 2017).

To develop the smart building that consumes less energy is achieved through connected technologies; General Service Administration (GSA) has also taken the steps to modernize government building federal states(Ning and Wang, 2011). The energy efficiency was achieved by integrating and connecting several low-cost sensors to fifty governmental buildings and estimated to save around 15 million annually. These buildings were aimed at gathering at least 100 nodes that transmit data and could be used for operational effectiveness in each building. After noticing the vigorous abilities, advantages of the smart buildings, US Department of State started to install online meters/smart meters to gain insights into energy consumption as well as water utilization (Ning and Wang, 2011). Nepal's federal government is also playing an important part in encouraging and supporting smart-building applications.

IoT, although in a budding phase, the ability of multiple units of IoT to connect over the global network, makes it omnipresent and omnipotent. Special applications, like a neural network that behaves and works like human, and underlying subsequent models underpin the future architecture of the Unit IoT. The future IoT can enhance the interpretation of the relationship between IoT and the reality around us and, in return, these interpretations empower further development of IoT. This interrelatedness works as a never-ending cycle (Ning and Wang, 2011). With the explosion of disruptive technology, it has become very difficult to draw the attention of users, and makes them adaptive to new technologies. Therefore, personalization has taken foremost importance in the development of technology to enhance user engagement. IoT has taken a similar approach but on a much larger scale. Instead of just targeting an individual, IoT solutions can address larger problems by connecting governments, cities, and people, and empowering them to serve each other on an unimaginable scale and in a multiplicity of ways. Thus, IoT works to personalize the engagement of society in technology by enhancing public services and derive a better way of living (El-Haddadeh et al., 2018).

Most of the digital filters are used to remove unwanted signals called noise, and are also used for shaping the spectrum, and to detect the signals for analysis. There are two types of digital filters namely, Infinite Impulse Response (IIR) and Finite Impulse Response (FIR) filter that are used for shaping the spectrum, and detect the signals for analysis. Filter applications mostly include low pass filtering, range of frequency, or band selection, and signal preconditioning as well.(Gautam et al., 2015). The shaping of spectrum of the signals received from the ultrasonic sensor is important, these aspects are more important when we interface sensors in any IoT system.

The extraordinary rate of urbanization, as well as the resulting increase in the size and number of cities in various parts of the world bring both challenges and opportunities. The tenfold increase in urban population (from 250 million at the turn of the twentieth century to 2.8 billion at the turn of the twenty-first century, with an expected increase to around 9 billion in 2050) puts traditional approaches to city management and urban lifestyle under strain. For example, the old approach to managing transportation networks, water resources, trash, energy, and the natural environment in cities must be radically rethought in order to cope with the pressures created by increased demand for these resources in a sustainable manner. On the other side, given that, cities are the social centers of larger societies, providing much-needed intellectual and social capital for growth, and, since larger cities tend to be able to achieve more productivity with less resources, city growth may provide chances for better city administration and innovation. The collaborative creativity fostered by cities' proximity and frequent exchange of ideas have aided many cities, particularly in the developing world, in escaping poverty and integrating into the global economy. Many governments at various levels. International, regional, national, and local—have launched projects on digital and intelligent cities, and more recently smart cities, in response to the difficulties and potential of rapid urbanization and city growth. Digital, intelligent, and smart cities are all related ideas that involve the change of the city, city management, and city residents and actors through the use of information and communication technology (ICT). While the distinction between the three concepts is hazy, changes in the changing focus and, as a result, the requisite capabilities in implementing projects linked with the three concepts have been highlighted. Smart cities, as urban innovation and transformation initiatives, aim at harnessing physical infrastructures, information and communication technologies, knowledge resources, and social infrastructure for economic regeneration, social cohesion, improved city administration, and infrastructure management. The significance of people or the well-being of its population in the smart city concept is a distinguishing quality. Smart cities are specifically concerned with the transformation of city residents' lives and jobs. Smart cities also emphasize human engagement for the generation of ideas, which are the money of the modern period. This extended scope and focus on integration of different aspects of city—administration, resource management, lifestyle, mobility, etc.—makes the smart cities' research more challenging and ambitious with respect to previous research on intelligent and digital cities which focus primarily on the technology dimension (e.g., ICT infrastructure and services) and its transformational effect on other dimensions of the city (Dijkman et al., 2015).

IoT devices, such as sensors, actuators, and smartphones, etc. are very fast and valuable sources to meet the needs of urban public and city development smartly. However, joining thousands of IoT devices and allowing them to communicate with one another over the Internet to create a smart system generates a massive amount of data, which is referred to as Big Data. Integrating IoT services in order to obtain real-time city data and then efficiently processing such large amounts of data in order to establish a smart city is a difficult task. Smart home sensors, vehicle networking, weather, and water sensors, smart parking sensors, surveillance objects, and other sensors have been deployed.The complete architecture and implementation model is proposed, and it is implemented in a real-world setting using the Hadoop ecosystem. Data production and collection, aggregation, filtration, categorization, preprocessing, computing, and decision making are the steps performed for system implementation.The efficiency in Big Data processing is achieved using spark over Hadoop. To establish a smart city, the system is realistically realized by using smart systems as a municipal data source.(Qiu et al., 2015a)

It is not a new concept to use information and communications technology tools and techniques for city administration, whether for urban planning activities, transportation solutions, or for a variety of other goals. However, in order for a city to be classified as 'smart', a synthesis of intelligence that transcends mere utilization is essential. The rising use of information and communications technology, as well as sensing technologies, in cities is analyzed, which takes a critical look at a new manner of city governance.(Thompson, 2015)

The detailed study of prevailing IoT frameworks indicates significant differences between the frameworks with respect to their context of study as well as the spectra of the components used in the framework and their entire level of expansion, their notch of differentiation, and notion. Most patently, the findings of this study illustrate the lack of knowledge that concentrates on the public sector and government as well as IoT frameworks. The in-depth study and examination of current IoT frameworks suggest significant differences from other IoT frameworks. These differences are noted on their factors of analysis, parts or constituents directed to the spectra of framework and their detailed information. Additionally, their angle of change or abstraction has noticeably illustrated gap between public services and government ones, well turned out about IoT framework(Wirtz et al., 2018b).

One of the study conducted in Surrey City of Canada depicted that the concept of IoT used in smart home 6000 houses consume more than 9000 cubic meters of water. This type of system can help the authorities to estimate the water billing rates based on the use of water. This study has also found that the flow of water to several areas depending on the need of an area can also be controlled. The forecasting done by the system can also help authorities to control water resources depending on their reservoirs. The water can be stored in reservoirs and distributed according to the water consumption parameter (Charef et al., 2000)(Rathore et al., 2016b).

Smart city in India

The government of India aims at renovating the urban landscape and retrofitting the current one to develop more citizen friendly and sustainable cities. Its strategies help modify existing but fully built up areas that would be way too costly to build from ground up, develop currently emerging areas with proper planning and technical infrastructures and straight up plan from ground zero for currently vacant areas, ripe for development and urbanization. It is also looking for ways to apply smart solutions to currently existing national infrastructures.The Major focus of the planned development of India is shown in Figure 2.1.

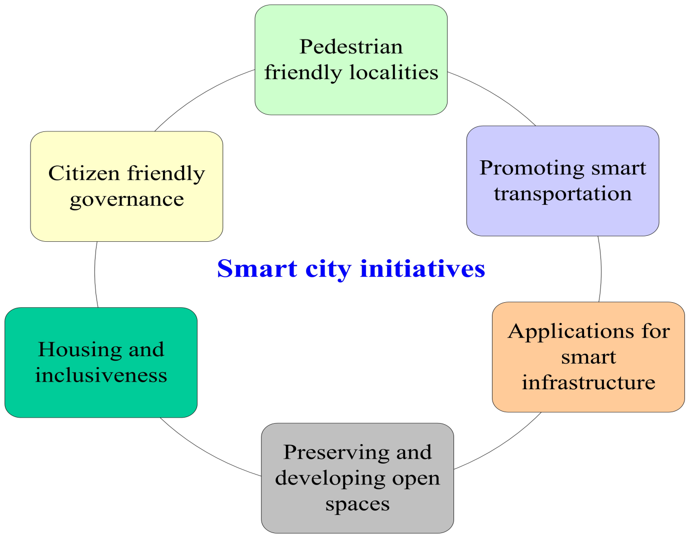


Figure 2.1: Major focus of the planned development

The resources for smart cities projects are to be collected through Government of India (GoI) funding, along with matching contributions by states and user charges. Encouraging Public Private Partnerships (PPPs), municipal bonds, borrowings from bilaterals and multilaterals, national investment and infrastructure fund (NIIF) and convergence with other Government schemes could also help accelerate the funding for the project, helping it come to life sooner.

A study of a city's water supply status was triggered when an issue of water loss and subsequent hike in energy costs in the city's water supply and operation cost was noticed. This study allowed the city to reach a conclusion to set up an automated water management system while replacing the old and inefficient pumps with more energy efficient pumps, pump machinery and having remote monitoring systems installed to operate the pumps at prescribed efficiency levels. This change in the water systems resulted in 106.96 Kwh/MLD reduction in energy consumption and saved the city over 10 crore rupees in operation and management costs. It was noted that the average pumping efficiency improved from 40% to 75%.

Smart city in China

The Concept of developing smart cities in China started in 2010, and over 300 cities have been identified for piloting the smart city development projects. Five characteristics that influence the establishment of smart cities in China are:

1. The development of smart cities should be guided by a green and low-carbon

lifestyle, as well as user-friendliness.

2. Giving smart city development a high strategic priority, with a focus on overall coordination and top-down design.
3. Taking advantage of planning and development advantages to bring advanced development to their areas for new cities and districts.
4. Developing smart city clusters to promote inter-city co-development.
5. Speeding the construction of smart cities in the central-western area and underdeveloped mainland regions in order to stimulate rapid development.

Smart city in Hong kong

It is home for eight government funded universities, and is the only city in Asia to average more than one transit ride per day per capita. It is also known for actively leveraging information and communication technologies (ICT) to improve efficiency of its services to its citizens. It ranks 5th in the world and 2nd in the Asia/Pacific region in the Rutgers study of e-governance.

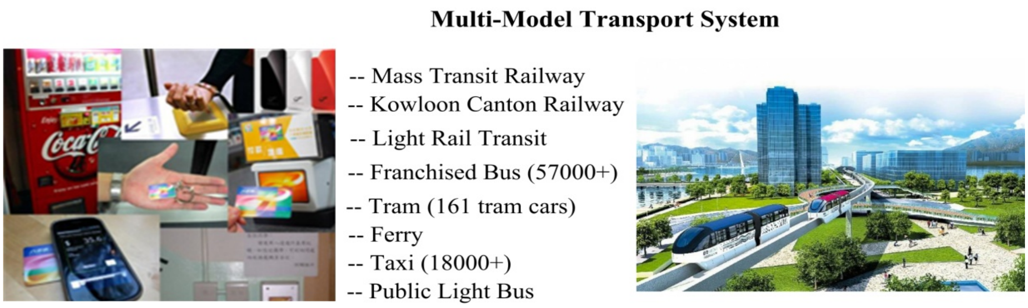


Figure 2.2: Use of vending machine and multi-model transport system in Hongkong

The city boasts one of the first and most successful smart card programs for citizens (Octopus card), which allows residents to pay for public transportation and parking, as well as schools and, in certain circumstances, admission to smarter buildings, with only one card.

Smart city in New York, USA

The government of New York City and Cisco IBSG collaborated to build Smart Screen City 24/7, a pioneer in smart city development in the United States.Old phone booths have been turned into smart screens (Wi-Fi hotspots), allowing the public to access information at any time. The Hudson yards project aims at creating a commercial and residential district on Manhattan's west side, complete with computerized sensors that monitor traffic, energy use, and air quality in real time.

Smart city in Songdo, South Korea

Songdo stands as an entirely new smart city pilot project being built from the ground floor up with sustainability and technology in mind. It has cost $40 billion so far and is located within the Incheon Free Economic Zone. It is fully owned by private investors, making it the world's largest private real estate venture. It is the second city in the world to have all of its main buildings at or below the levels specified by the green energy certification, LEED (Leadership in Energy and Environmental Design), with 80 percent of its funding dedicated to green technology. Songdo's main focus is on long-term sustainability. There are numerous charging stations for electric cars strewn across the city, as well as a waste collection service that eliminates the need for garbage trucks entirely.

Smart city in Istanbul, Turkey

Istanbul is a member of the European Union's ICT Policy Support Program-funded City SDK (Smart City Service Development Kit and its Application Pilots) initiative. The Istanbul Metropolitan Municipality (IMM) has been awarded a grant from the United States Trade and Development Agency (USTDA) to improve its operations by procuring improved IT solutions and developing a cloud-based environment capable of aggregating data from existing municipal databases and information inputs. The Pedestrian Electronic Detection System initiative intends to reduce intersection delays and eliminate dangerous gas emissions.

Smart city in Singapore

Of one hundred and nine global cities, the Institute for Management Development (IMD) Smart City Index 2020 ranks Singapore as the 'smartest' city. The information assembled from the survey demonstrates the combination of technology, habitability and leadership in the metropolitan premises. The city state is driven persistently by the idea of becoming a digital innovation hub. In today's date, no city city can challenge Singapore in terms of smart commutation, security, healthcare, systematic governance and overall living standard. Providing collaborative and community-oriented models has been the work philosophy of Singapore. An example is the initiation of community-centred healthcare projects like Health City Novena (Subhankar, 2020). Singapore has worked on collaborative and people-centric models. The development of community-focused healthcare projects like Health City Novena is one of such examples (Subhankar, 2020).

Adopting innovation to provide quality healthcare, a healthcare environment has been developed by Singapore. As it is, strong manpower is defined by a healthy population. With the use of modern digital and remote technologies, healthcare facilities have been established for the elderly population too.

According to Safe Cities Index 2019, Singapore is ranked among the world's safest cities with the institution of over half a million police surveillance cameras and web-based police portals. A 'smart' city is indicated by the urban security levels and technological strength. And Singapore is the second to none at this (Subhankar, 2020).

Systematic public commutation systems have been established by the Singaporean authorities to provide modern commutation facilities. The city has highly systematic, affordable, convenient and environment-friendly transit networks. The affordable and convenient transportation has enabled people to lead a mobile lifestyle.

The 2018 McKinsey report shows Singapore to have the best-in-class commutation system. Implementing smart technology, the authorities have instituted smart, consumer-friendly and sustainable traffic solutions. Shared and public commutation provisions are enforced , with the strict policies discouraging car ownership.

The city-state has instituted convenient mobility solutions for its citizens. And, as a fitting complement to the public transport in Singapore, the station shared few bicycles and bikes, and electric carpooling services like BlueSG have flourished here. In addition to that, the construction of infrastructure is in progress with the motive to embrace active mobility modes like cycling and/or walking with public transit networks (Subhankar, 2020).

Smart city in Romania

Alba lulia, Cluj-Napoca and Bucharest are some cities in Romania that are taking significant initiatives to implement smart city (Bandyopadhyay and Sen, 2011). These cities are important from touristic, cultural, economic, and industrial perspectives. Effective utilization of resources, knowledge based economy, modest economy, and creativity as well as innovation is a pre-requisite for sustainability and growth of any city, and these are possible by making the city smart(Byun et al., 2016). Cities operate with a high efficiency, thereby providing and promoting improved services to citizens and existing businesses.
The following are the benefits derived from smart city:

- Better data, better decision
- Improved engagement between citizen and government for enhancing the life
- Safeguarding the communities
- Improvement in transportation facilities
- Heightened digital equity
- New arena and opportunities for economic development
- Improvement in the existing infrastructure

2.2 Smart Traffic Management

Transportation has always been one of the major problems here in Nepal. People have to get into their buses almost an hour before, because traffic jams are always a problem, especially in Kathmandu. The traffic system is not well managed, which leads to almost 40 (average) accidents every day in Nepal. Emergency vehicles are not given priority because of which many people die due to late treatment.

We can use the Internet of things and data analytics to create a smart traffic management system to solve some of these problems. People can check free parking spaces and prices of parking fares at different locations with their smart phones. They can also make reservation and payment for parking spaces (Bagula, 2016). Since all the data about the parking spaces will be stored, illegal parking can also be lowered. Through the use of such a system, it becomes easier and faster for people to report illegal activities. We can also predict the traffic congestion at real time, which makes it easier for people to travel from one place to another, and set priorities for emergency vehicles such as ambulance, fire trucks, etc. so that such services can be provided to people on time. We can also prevent road accidents by designing these systems which will alert the drivers if their vehicle is getting close to any human being or other objects so that the drivers can take measures to prevent accidents (Nowicka, 2014).

2.3 Smart Education

Smart education service provides interactive high-definition lectures at home through high-definition services (HD) and wide-area internet infrastructure. This also allows students from all around the world to participate in lectures held by foreign teachers from other countries, comfortably from their homes (Assante et al., 2019). The schematic of smart education service diagram is shown in Figure 2.3.

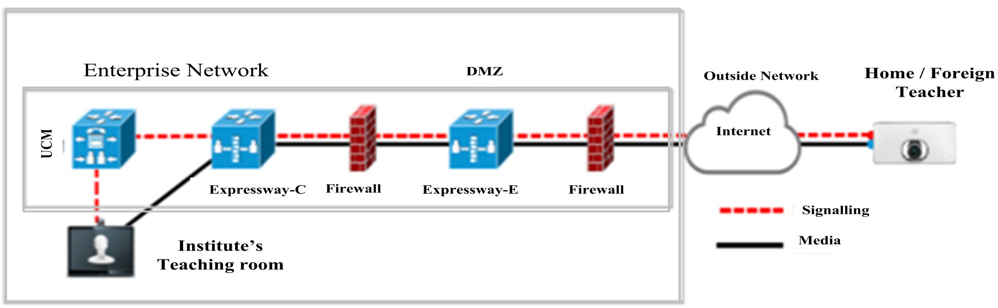


Figure 2.3: Smart education service diagram (Assante et al., 2019)

2.4 Smart Healthcare

If information about the biorhythms of an individual is saved regularly , we can reduce medical expenses and it also helps to discover diseases in an early stage. Storing the health status of a patient regularly also helps doctors keep track of patient's health more effectively. Employing these kind of devices are especially helpful for rural people who might not have the access to immediate help from doctors or facilities to travel to hospitals. The system can be configured so that it periodically collects the data of the patient and sends it to their family doctor, health posts, etc. through big data analysis via mobile devices. We can allow users to access the portal and check their health information, which also results in transparency between the doctors and the patients. Since various images are required during the screening of the patient, images can be easily exchanged from one hospital to the other, which saves the cost of duplicate image data. If designed properly the smart health care system can be of great help specially for people in remote areas and for people who live alone(Nowicka, 2014)

IoT can help to better predict the disease, some biodegradable chips are being used to know about the disease a patient is suffering from. The supply chain management can be made more efficient injecting IoT in distribution process by using sensors in the network (Miazi et al., 2016). IoT helps in tracking of the medicines transported from one place to another. Hence, IoT has a great future in medical and pharmaceutical fields as well. The prospective applications of IoT are countless and can have direct impact on the community (Miazi et al., 2016).

2.5 Air Quality Management

Kathmandu has already witnessed world's most polluted air many times. This has resulted in the degradation of the quality of life not only for humans, but for all the living beings here. We can use Internet of Things and a cloud computing technology to monitor the air quality anywhere at any time. Various sensors can be used to monitor the level of various gases, such as carbon dioxide, carbon monoxide, aerosols, etc. present in the air, and data from these devices can be analyzed by a web server using cloud computing to visualize and classify the air quality according to the standards set by the concerned Ministry (Zanella et al., 2014) (Lynch and Loh, 2006).

In addition, health applications in various devices can also be provided with this information so that people can always find the healthiest place for outdoor activities and can be continuously connected to their preferred personal training activities (Nuortio et al., 2006).

2.6 Managing Noise Pollution

An urban IoT can provide a noise monitoring service to measure the quantity of noise produced in the places that use the service at any given hour. The digital values of sound pollution make the user more aware about the noise pollution around them, and helps them to plan for a healthy living and surrounding. Aside from creating a space-time map of the area's noise pollution, such a service can also be utilized to enforce public safety by employing sound recognition algorithms that can detect noises, such as glass crashes or brawls (Al-Ali et al., 2010).

2.7 Smart parking

Proper monitoring of traffic congestion for smart cities can be achieved through urban IoT by low power widespread communication which is not the case at present. Devices like GPS and other sensing devices can be used for proper traffic monitoring along with other air quality sensing sensors. This brings positive impacts on both authorities and the general public (Maisonneuve et al., 2009).

An urban IoT can also be of service that provides information about the energy consumption. This will help in efficient management of energy consumption and can also help enhance the sectors where the energy consumption can be optimized (Maisonneuve et al., 2009).

Urban IoT can also help in managing parking systems efficiently as there is less CO emission and also saving time while parking vehicles. Technologies, such as RFID (Radio Frequency Identifiers) and NFC (Near Field Communication), can be integrated into urban IoT to achieve smart parking systems (Li et al., 2009).

Proper management of street lights can be achieved via urban IoT which results in efficient utilization of energy consumption as well. The intensity of the street can be made to change according to the time, weather and population density (Li et al., 2009).

2.8 Automation of Public Buildings

Automation of public buildings can be done with the help of IoT. Different sensors can be used to read the current data, such as humidity, temperature around a certain building, and the systems, such as heater or ac, can be used efficiently for proper production along with efficient use of energy (Lee et al., 2008).

Table 2.1 shows the service specification for the Padova smart city, and this findings can be important for constructing smart cities in other areas as well.

Table 2.1: Services specification for the Padova smart city (Zanella et al., 2014)

Service	Network types	Traffic rate	Tolerable delay	Energy Source	Feasibility
Structural health	802.15.4; WiFi and Ethernet	1 pkt every 10 min per device	30 min for data; 10 secs for alarms	Mostly battery powered	Easy to realize but seismograph may be difficult to integrate
Waste management	WiFi; 3G and 4G	1 pkt every hour per device	30 min for data	Battery power or energy harvesters	Possible to realize, but requires smart garbage containers
Air quality monitoring	802.15.4; Bluetooth and WiFi	1 pkt every 30 min per device	5 min for data	Photovoltaic panels for each device	Easy to realize, but greenhouse gas sensors may not be cost effective
Noise monitoring	802.15.4; and Ethernet	1 pkt every 10 min per device	5 min for data; 10 secs for alarms	Battery power or energy harvesters	The sound pattern detection scheme may be difficult to implement on constrained devices
Traffic congestion	802.15.4; Bluetooth and WiFi; Ethernet	1 pkt every 10 min per device	5 min for data	Battery power or energy harvesters	Requires the realization of both air quality and noise monitoring
City energy consumption	PLC and Ethernet	1 pkt every 10 min per device	5 min for data; tighter requirements for control	Mains powered	Simple to realize, but requires authorization from energy operators
Smart parking	802.15.4; and Ethernet	On demand	1 min	Energy harvester	Smart parking systems are already available on the market and their integration should be simple
Smart lighting	802.15.4; WiFi and Ethernet	On demand	1 min	Mains powered	Does not present major difficulties, but requires intervention on existing infrastructures
Automation and salubrity of public buildings	802.15.4; WiFi and Ethernet	1 pkt every 10 min for remote monitoring; 1 pkt every 30 degree for in-loco control	5 min for remote monitoring, few secs for in-loco control	Mains powered and battery powered	Does not present major difficulties, but requires intervention on existing infrastructures

2.9 Smart City initiatives in Nepal

According to the budget speech of Nepal in 2015/16, there is a master plan to build green cities and smart cities. It has been planned to build Green Cities in Dharan, Pokhara and Lalitpur and Smart Cities in Lumbini, Kathmandu and Nijgadh, and it is depicted in Figure 2.4.

According to program and policies formulated in 2015/16 under section 92, it is evidently clear that mentioned that keeping palungtar of Gorkha at center smart cities will be developed. The policies also focus on promoting the usage of electric vehicles, accelerating the use of 4G services and 72 district headquarters to be connected by high speed internet. In Kathmandu a total of 6613.62 hector land has been allocated to develop smart city, and it is depicted in Table 2.2 (Joshi and Manandhar, 2019).

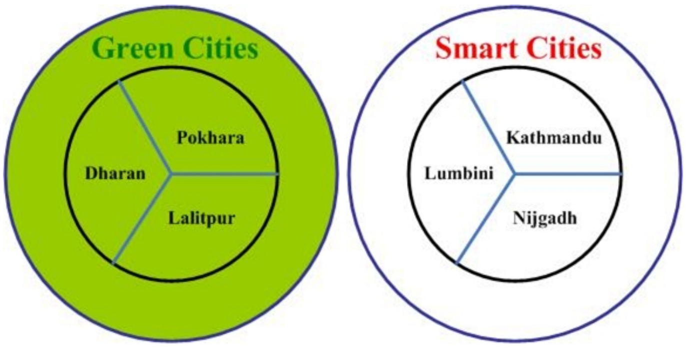


Figure 2.4: Green cities and smart cities in Nepal (Karki and Dahal, 2020)

The Internet of Things is a recent technology that helps connect a lot of sensors that generate the data according to its types, and creates a plethora of space to develop smart cities. One of the important concepts for the development of any country is smart city. It is significant for the government of Nepal to offer several IT enabled services to its citizens and the fact is that IoT helps significantly to achieve this service. The possibility to communicate transparently and seamlessly with higher number of similar and different systems increases by having access to the data that has been designed to flow in providing digital services.

The execution of the plan to create smart city is a daunting task and requires rigorous assessment. There are various barriers and hindrances to creating the smart city, but it is difficult to predict those barriers and hindrances. It is therefore an interview with high level government officials, and IT specialist which has been carried out to get insights on the prevalent underlying infrastructure status in building smart city in Nepal.

Table 2.2: Land allocation to develop smart city (Joshi and Manandhar, 2019)

SN	Category	Coverage
1	First: 5087.4 Hector	From Mulpani Cricket Stadium main road extended to Sankhu, From Salinadi to Telkot, Tikhlapakhe planning of Bhaktapur including Kharipati except Kharipati Army Baroque, Bode and again from Manohara to Mulpani Cricket Stadium.
2	Second: 508.74 Hector	Starting from the base of Suryabinayak jungle Bhaktapur to Lamatar river, Balkot, Araniko highway, Kausaltar and again to Suryabinayak.
3	Third: 508.74 Hector	Khokana, Bungamati, Sainbu Colony, Being from Bagmati suspended bridge to Chovar.
4	Fourth: 508.74 Hector	Main road to Tarakeshwor municipality, Simleshwor, Being from Jhor to Fulbari Marga, Tokha to Bypass.

2.10 Overview of Plans and Policies regarding smart cities in Nepal

Voice about smart city implementation has started emanating from different nook and corner of Nepal, and, the first national agenda was seen in the budget speech of 2016/17 (Joshi and Manandhar, 2018).

2.10.1 Budget Speech of Nepal 2016-17

A clear blueprint is planned to be designed and it includes Kathmandu, Lumbini and Nijgadh for smart cities and Pokhara, Dharan and Lalitpur for green cities. A legal statement regarding is mentioned in section 224 as ”The development of smart city will be initiated by laying the optical fiber in the mid-hill highway with the utilization of rural telecommunication development fund. Continuity will be given to establish the rural information centers.” (Joshi and Manandhar, 2018)

2.10.2 Nepal Government’s Policies and Programs of 2017-18

The major portion of the policies promulgated in 2017/18 regarding smart city is mentioned in section 65 as; ”Cities will be made the base of economic growth by developing rural-urban inter linkages. Few smart cities will be built in various parts of the country. ” (Joshi and Manandhar, 2018)

2.10.3 Budget Speech of 2017-18

The major focus of budget speech of 2017/18 is mentioned in Section 92 as; ”Keeping Palungtar of Gorkha at a center, smart city master plan will be developed and implemented in the surrounding areas of Marsyangdi. In order to develop Walling, Lumbini and Dadeldhura including 10 cities as modern and prosperous smart cities, infrastructure construction work will be initiated through preparation of the master plan.” (Joshi and Manandhar, 2018)

This budget speech also focused on:

1. Encouraging the usage of electric vehicles (Joshi and Manandhar, 2018).
2. Deployment of 4G services in sub-metropolitan cities in Kathmandu. (Joshi and Manandhar, 2018)
3. 72 district headquarters to be connected with high speed internet connectivity using optical fiber deployed via highways (Joshi and Manandhar, 2018).
4. Making free internet access to the schools and colleges of rural community by deploying Rural Telecommunications Development Fund (RTDF) (Joshi and Manandhar, 2018).

2.11 Experts' opinions on Smart City in Nepal

People define smart cities in their own way of understanding. However, the common opinions of experts regarding smart cities are listed below:

- Penetrating online transaction and using ICT to access education, agriculture, health, and so on.
- Smart city means environmental protection, efficient means of transportation and also the resilient characteristics of a city to a disaster.
- Some say that the cities were smart traditionally, regarding the infrastructure and efficient governance.
- To make the city smart, the city should select itself the indicators which should be centrally focused.
- While implementing smart cities, culture and tradition should not be destroyed.
- The infrastructure and services that should be given more priority must be picked up by the city itself in order to make any city smart.
- In a smart city, citizen should be in a focal point.
- Legal procedures are more important than technological infrastructure to form a smart city.
- The status of infrastructures should be known in prior to gain insights regarding what kind of smartness is required for a city to be smart. Government services should include ICT during service delivery.

2.12 Sensors and layers in IoT framework

With the expansion in miniaturization of the internet, connected objects that collect and exchange data, in the past decade many such data have been produced. Due to a number of data, IoT, and analytical solutions, many resourceful intuitions have been perceived by the people with data generation through the IoT devices. Nevertheless, these resolutions are at their early stage with the deficit of an extensive study on a domain (Marjani et al., 2017). Without monitoring, anything cannot be controlled, and this applies to water resource management as well. A system based on IoT for monitoring water resource and managing it is formed by uniting 3 different layers: The device perception layer, the layer for information communication, and the third layer called as application layer (El-Haddadeh et al., 2018). In the first one sensor network is constructed. In the second layer, real-time data is acquired and in the third layer, information about water like the amount of water consumed, leakage information are stored. This data is then managed using several IT tools and finally, it is shared by the end-users over the internet (Shaohong, 2015). It is pretty much difficult to detect the impurities contained in the water just from our naked eyes; to overcome this difficulty turbidity sensor can be used. It helps to identify the particles floating in the water. This sensor works by emitting the light beam in the water and this light is scattered if any solid particles are suspended (Gupta et al., 2018). The turbidity sensor is placed at 90 degree against the water surface when it gets back the reflected light. Comparison between the transmitted and reflected amount of light can be used to investigate the thickness of solidified elements existing in the water (Gupta et al., 2018). It is really challenging to foster support for two different domain applications and build system software as well as platforms in IoT (Alhaj Ali, 2018). Several investigations and standardization exertions have been put for maintaining the compatibility issues associated with the heterogeneity in IoT devices and the protocols related with communications (Alhaj Ali, 2018)(Thangavel et al., 2014). These efforts have a great weight to deal with IoT frameworks and layers related to service interoperability (Barolli et al., 2021). The system can go beyond the embedded system when it is linked with the internet, thereby making the connected objects to sense and communicate. This robust feature of IoT can take multiple advantages from super-computing nodes remotely (Bauer and Joachim, 2013). Complex decision taking tasks and responding to the local needs can be done very fast with IoT based system without requiring human intervention (Bauer and Joachim, 2013). Technological content in smart city embraces a ’smart life-style’ by improving the security of lives, assets and properties, utilization of energy, minimizing the waste as well as transportation and parking services (Segaran et al., 2020)(Cardullo and Kitchin, 2019).

Monitoring the water supply pipeline, quality of water in the water source, online meter reading, and security measures in IoT are the features of smart water applications. Most of the digital filters are used to remove unwanted signals called noise. Maintaining and ensuring the security of connected devices is always essential; this plays a role in establishing the integrity of information of clients/customers. For this only relevant data/information can pass from the network in IoT and essential frameworks or methodologies were established (Pacheco et al., 2017). It was also important to monitor the quality of water by effective usage of IoT applications and electronic components/devices associated with it. The significance of this application helps preserve the quality of water and safeguard the health of people living around it. This system has been economical and uses inexpensive devices and virtualization of the network (A.N.Prasad et al., 2015)(Menon et al., 2017). One of the other applications was developed to detect leakage in the water pipe. Several IoT devices, deployment of cloud services as well as concepts of Wireless Sensor Network (WSN) were applied in detecting the leakage and alert user. The significance of this application is to know the amount of water wasted by leakage (Gerkey et al., 2003). In recent days, wastewater monitoring and treatment using IoT is emerging, and this application would be useful for household activities and saves water to a great extent (Vinodini Ramesh et al., 2017)(Qi et al., 2017). The growth in technology has served to develop effective and efficient methods to solve many problems or serious issues. IoT has paid big attention because of its fast processing and intelligent characteristics (Yokota et al., 2018).

The technology in IoT helps ease the automatic management of water which is a valuable resource. This technology also helps ensure the quality of water by using a turbidity sensor in the system. In the architecture known as Smart Water Distribution System (SWDS), IoT and technologies related to the cloud are used for erratic water supply. Most of the previous research works done assumed a continuous supply of water. None of the pragmatic steps were taken at any phase, only rhetoric aspects were discussed. The research entitled Smart Water Distribution System plays a key role especially in developing countries where the irregular supply of water is prevalent (Alshattnawi, 2017). To enable the monitoring and control of the water grid equipment thousands of sensors are deployed in the distribution network for an efficient water management system. However, the security procedures at the network level should not be undermined. Though several security provisions in IT and control procedures have been developed in the previous years, these cannot be directly used with the devices used in IoT applications (Ntuli and Abu-Mahfouz, 2016).

Each sensor is assigned an IP address through the micro-controller and router to interface them in a single system. This helps identify the sensors in the network. This task can be done by writing some lines of code in the Raspberry-Pi, a type of micro-controller, and provide a unique number to the sensors residing in the system. An experiment was conducted to assign the IPV4 address where multiple sensors, Raspberry-Pi, and TP-Link router were used and the experiment became successful (Gautam and Sharma, 2019). Smart city incorporates efficient storage and processing of data and generates information that can help enhance the lifestyle of the people, and that task is done by most of the applications of big data. These types of applications aid in decision-making regarding the expansion of the service offerings in any smart city. Nevertheless, the right procedures and tools are needed for effective analysis of data (Gautam et al., 2015). These procedures and tools might in turn inspire communication and collaboration between related entities and provide amenities to many areas in the smart city. These characteristics enhance customers' experiences and provide several business opportunities (Hashem et al., 2016).

2.13 IoT framework in water supply sector

To check the authenticity of the statistics regarding water usage and to predict future need the skewness measure has been used. Univariate usage of water consumption W_1 ,W_2, W_3 . . .W_N is given by the following formula of skewness.

$$S_k = \sum_{i=1}^{N} \frac{(W_i - W^-)^{\frac{3}{N}}}{S^3}$$

Where W$^-$ is the mean, s is the standard deviation, and N is the number of data points. While computing the skewness, the s is computed with N, rather than N-1 (Rathore et al., 2016b).

Algorithms have been developed to obtain the data of the soil moisture that is essential for smart irrigation system using IoT. Web service has been used for data collection from sensors, and these data have been utilized in performing the statistical analysis to predict the soil moisture. The real time monitoring of the soil moisture contributes to agricultural sector to a great extent (Goap and Sharma, 2018).

In IoT applications, WSN has a lot of uses. Float sensor is used to compute the channel of water in the tank. As elevation differences have a direct impact on the transmission, mostly nodes are placed in the vicinity of ground having 50 cm as the height of trough. The antenna of the hub is positioned 8 m above the ground. To meet this requirement and also due to the accessibility of free frequency, LoRa™ with 915 MHz center frequency is used in preliminary design. In this system, HopeRF RFM95 is used as the alternative product of LoRa™. Atmel ATmega328 is used to take the input of water level in trough in the node side (Kamienski et al., 2019).The overall topology of the system is depicted in Figure 2.5.

In the sensor hub, Raspberry Pi 1 model B is used having 512MB RAM. Since ATmega consumes low power, it is used in nodes targeting at the application in remote places. Raspberry Pi is used to control the sensor hub as it behaves like the property of

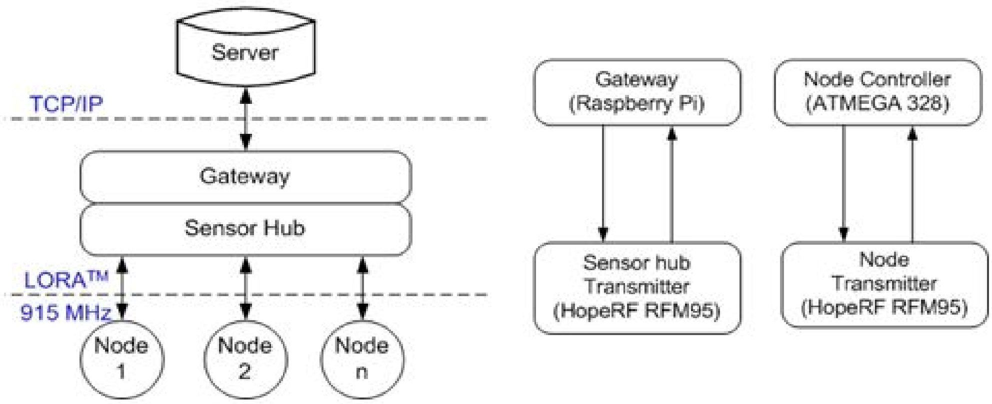


Figure 2.5: Topology of water level monitoring system (Kamienski et al., 2019).

system on chip and embedded system having SPI to commune with HopeRF RFM95 (Kamienski et al., 2019).

In a research named "Smart Water Management Platform: IoT-Based Precision Irrigation for Agriculture", experiments were conducted with many sensors that send data in an interval of 10 min. Each experiment lasted for one minute, and was repeated 30 times, totaling 16 hours of running time. With a confidence level of 99 percent, asymptotic confidence intervals were determined. This configuration captured the response of a connection from the farm to the cloud using 4G connection, with 10 Mbps speed and a delay of 45 ms with a jitter of 5ms. The result of the experiments concluded that while using MongoDB the utilization of CPU increased with the increasing numbers of sensors, and the usage of RAM increased while using the IoT agent (Lukas et al., 2015).

For implementing the smart water system using IoT, the sensors are placed in the center of the inner side of the tank cover, and these sensors continuously provide information on the real-time status of water. This information will be updated on the cloud, and some cell phone applications can also be used to visualize the level of the water in the tank. The automatic functioning of the motor controls the amount of water in the tank (Yadav et al., 2016).

The development of the IoT framework requires an experiment, review of literature, survey, and analysis. After performing all these activities, we need to verify and validate the developed framework using scientific methods. In this paper the type of experiment and survey we performed has been summarized and presented as a result of the survey, and finally using rigorous analysis, a framework has been recommended.

Paradigm shifts were found in managing Water Distribution Network (WDN) that is mainly focused on minimizing the waste and leakage of water. Latest study has found that employing smart meters makes it easier for users. The data were collected in

District Metered Area (DMA) in two ways: when the smart meter was placed in every place, and when it was absent. The former technique used Fisher's test as a stopping condition and is based on stepwise regression to evaluate demand time series. The second technique looked at user types and yearly bill usage. A case study in Italy was used to test both approaches. The findings showed that as the sample size grows, the efficiency of gross demand pattern reconstruction of both techniques improves (Fiorillo et al., 2020b).

Unique opportunity can be created by the fusion of smart meters and big data analytics in case of water management. A data driven approach incorporating, extracting information on heterogeneous water end-use routines, the use of component in the user side, and temporal characteristics by using smart meter has been done. This approach has been tested in 327 households in Australia. The result revealed three main water use profiles, shower, clothes washing and irrigation. Difference between usage time and the intensity of use existed in each class. Customer segmentation and analysis approach found that a concise snapshot of recurrent water use routines from the smart meter could be used to support the demand management strategies in water supply sector(Cominola et al., 2019).

The case studies done in Italy with top-down and bottom-up procedures having two phases on each are compared with generating the water demand time series. The first phase of top-down approach has non-parametric disaggregation based on k-nearest neighbor, and the second phase used disaggregation to generate water demand time series at lower level of spatial aggregation. On the bottom-up approach, the first phase adopted beta probability distribution or gamma distribution, and the second phase applied copula based re-sort to enforce existing rank cross-correlations between users and temporal lags. Among the two approaches, the bottom-up performed better with skewness and cross-correlation (Fiorillo et al., 2020a).

A simulation was performed by evaluating three real case studies that followed stochastic modelling approach that retains the distributional and dependence properties of the process. The modelling technique is based on Nataf's joint distribution model to build the processes with the target marginal distribution and correlation structure. The simulation outcome depicted the efficiency of simulation technique in terms of recreating the varieties of marginal and dependence properties (Kossieris et al., 2019). Firoillo used smart meters in his research to get the consumption data in DMA. He used two approaches; when smart meters near the end of life were installed earlier at all locations, and when no smart meters were present. The result showed that accuracy of both approaches increases with the sample size (Fiorillo et al., 2020b). The study focuses on getting data from smart meters and applying statistical models to check the accuracy of data.

Lysis is a cloud-based platform for the deployment of IoT applications. The major features that have been followed in its design are designed in such a way that the PaaS(Platform as a Service) is fully exploited, and re-usability of different layers is considered by ensuring the improved network scalability and maintains the information discovery efficiency.(Girau et al., 2016).

The re-usability allows the programmers to generate templates of objects and services available to the whole Lysis community.The data generated by the devices is stored at the objects owners cloud spaces (Girau et al., 2016).

The Social Internet of Things (SIoT) is a paradigm which is rapidly gaining ground in the Internet of Things (IoT) domain. In the SIoT objects can establish social-like relationships between each other autonomously (Farris et al., 2015)

Xenochristou and Kapelan explained the steps for model development process which includes the selection of the spatial aggregation levels and candidate input variables, as well as the description of modeling techniques, its implementation and evaluation. Demand of the water was forecasted by training the models by obtaining the spatial data regarding water consumption (Xenochristou et al., 2020). This model is based on the machine learning as well as statistical analysis and the system has to depend on the external entities to obtain data.

Several research works have been conducted in past and the comparison of the research done previously is depicted in Table 2.3.

2.14 Comparison of IoT Frameworks

Though the different frameworks as presented in Table 2.3 and other relevant research works have their own features and limitations, they have significant role in knowing if we are reinventing the wheel. Almost all of the frameworks have limitations of particular protocols, microcontroller, OS, network, security and scalability. However, in the IoT framework developed in this research is somehow related to the IoT frameworks as mentioned in Table 2.3 and fits for almost all of the IoT applications and can be said as a generic IoT framework.

Table 2.3: Comparison of different IoT frameworks

SN	IoT Framework	Features	Limitations
1	Allerin (Zdravković et al., 2016)	i. Security, identity, and data permissions should be given the highest priority ii. Stimulate innovation iii. Reduce product development life cycle iv. Offers business intelligence, Information security, UI/UX design, Mobile integration, embedded systems with Networking and communication.	Very general framework and does not include technical specifications required for implementation
2	Kaa (Kuzovkova et al., 2020)	i. Scalability of connected devices ii. Effective monitoring of the system iii. Information exchange between linked devices	The macro-level framework can be challenging for the one who wants to bring IoT framework into action
3	Cisco Cloud Connect (Kuzovkova et al., 2020)	i. Powerful, automated, and high security in connectivity ii. Uses Cisco Kinetic IoT platform to extract, move and compute the data	The complexity associated with the IoT framework and more concentration against threats with a secure IoT architecture
4	Zetta (Nakhuva and Champaneria, 2015)	i. Server-oriented platform based on REST and NodeJS ii. Reactive programming philosophy adopted iii. Geo-distributed network	Limited to Arduino and Linux
5	Salesforce (Botta et al., 2015)	Entertains proactive and personalized activities from any device to bring clients closer	More administrative tasks are focused on.

SN	IoT Framework	Features	Limitations
6	Device Hive (Kim et al., 2019)	i. Deployment options for Docker and Kubernetes ii. Can run batch analysis as well as machine learning iii. Supports several libraries, Android and IOS are not the exceptions	Concentration on mobile applications is not enough to deploying IoT framework
7	Oracle IoT (Hoffmann et al., 2018)	i. Database management and business software ii. Flexibility in creating company applications iii. Supports the processing and builds large scale IoT networks iv. Usage of advanced security to protect against external security threats	Different devices have different security tool so it is not sufficiently justifiable to implement centralized security measures
8	SAP (Hoffmann et al., 2018)	i. Convenient environment to remotely manage and monitor all connected devices in the IoT framework ii. Use IoT information to machine learning and AI applications	
9	Microsoft Azure (Nakhuva and Champaneria, 2015)	i. Real-time data enabled in the server ii. Strongest safety mechanisms iii. Superb scalability iv. Simple integration	Use MS IoT suit to integrate the existing system to MS-Azure

SN	IoT Framework	Features	Limitations
10	Google Cloud Platform (Nakhuva and Champaneria, 2015)	i. End to end platform used to process the large quantity of information ii. Google's cloud data studio and Big Query advanced analysis can be done	
11	IBM Watson (Nakhuva and Champaneria, 2015)	i. Manages secure communication and data storage. ii. Real-time data exchange	Focus on data communication and its security
12	Hewlett Packard Enterprise (Alaa et al., 2018)	i. Data monetization ii. M2M device management	Product-based facilities offered
13	DataV by Bsquare (Sun et al., 2017)	i. Service orientation, hybrid framework ii. Works with Google, AWS, and Microsoft	Dependent on services offered by third parties
14	Mindsphere by Siemens (Endres et al., 2019)	i. Cost-effective platform ii. The stored information is strictly confidential iii. Open interface and local connectivity	An open interface is vulnerable to several security issues
15	Ayla Network (Ganguly, 2016)	i. Support customers ii. Agile platform	Limited to providing services regarding Mobile Application development

SN	IoT Framework	Features	Limitations
16	MBED Device Platform (Kuzovkova et al., 2020)	i. Uses Apache 2.0 Arm MBED computer platform ii. Designed MBED operating system	Open-source platform can be difficult to customize
17	Amazon Web services (Nakhuva and Champaneria, 2015)	i. Cloud computing, database, and security services through AWS console ii. Virtual Private Cloud (VPC's) offerings iii. Compatible software development kit for devices with Texas Instruments, Broadcom, and Qualcomm	No provisions for software development kit besides the devices with which AWS has been collaborating with
18	Mocana (Wang et al., 2019)	Cloud services with security	Only service orientation
19	RTI (Pazzi and Pellicciari, 2017)	Based on Connext DDS and does not require, response brokers, directory services, servers, as well as administration, unlike messaging middleware	Connext DDS built especially for smart computers and their cyber-physical systems

SN	IoT Framework	Features	Limitations
20	SenSquare (Montori et al., 2018)	i. Employs Community-Based Monitoring (CBM) ii. Concept of CrowdSensing is deployed iii. Deals with the heterogeneous data sources iv. Work on promoting Collaborative IoT (C-IoT)	i. Only temperature sensing is considered ii. Raises problem in quality of data in C-IoT
21	Low Power Wide Area Network in LoRa (Deese et al., 2021)	i. Employs Community-Based Monitoring (CBM) ii. Concept of CrowdSensing is deployed iii. Deals with the heterogeneous data sources iv. Work on promoting Collaborative IoT (C-IoT)	i. Only temperature sensing is considered ii. Raises problem in quality of data in C-IoT

2.15 Miniature Frameworks related to smart cities

The overall framework can be squeezed down into two levels namely, micro level and macro level as shown in Figure 2.6. The technology infrastructure level is referred to as the micro-level; this is because micro processing of data as well as sensor interfacing, and network computing are done in this layer.(Wirtz et al., 2018b). The macro level comprises of two layers one is government layer that helps in provide the government services like issuance of bill, inquiry for maintenance, and so on. Macro-level concentrates more on public services that are related to creating value and demand for the citizens, and this layer is referred to as the government layer (Wirtz et al., 2018b). This work emphasizes more on micro-level framework only. The micro level focuses more on technology related matters like integrating the sensors, issues regarding network and connectivity, the usage of Digital Signal Processing (DSP) chips and the matters related to the servers and data centers that are critical to ensure the availability of the data.

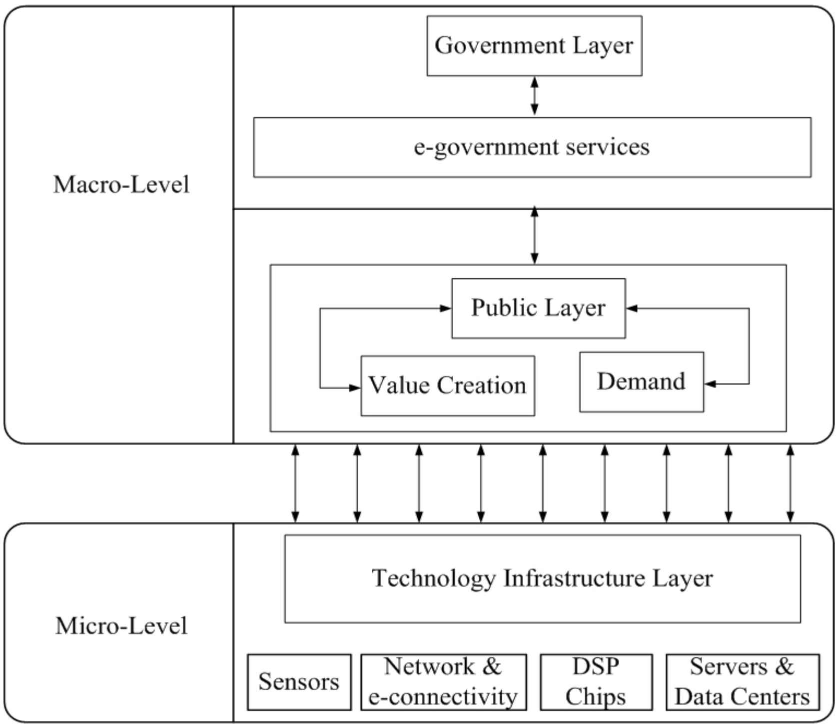


Figure 2.6: Interconnection of micro and macro level in IoT framework

Centralized decision on making smart cities, no public opinion collected; no study on level and conditions of infrastructure and population density are noticed. The current approach is still not people-centric. Lack of knowledge and large scale investment for initiation of smart cities projects need the implementation of a pilot project as a test before venturing into establishment of multiple smart cities.

From all these reviews of literature, it is evidently clear that till date none of the research scholars has developed the IoT framework for Nepal, and it is also an emerging topic in the global context. The concept of smart city in Nepal is burgeoning these days. If the frameworks are not developed in Nepal, we have to depend on foreign countries or international companies for IoT implementation. In a nutshell, the existing infrastructure should be analyzed, and based on those infrastructure, IoT framework must be developed to implement smart city in Nepal.

Water supply sector has been considered for this research in order to realize the IoT framework. However, this framework fits other areas like electricity management, home automations, agriculture, so forth and so on. Internet of Things (IoT), being a contemporary area, is attracting researchers in recent times (Wirtz et al., 2018b). Different types of definitions have been written by several researchers for the last two decades. Some emphasize the network character of IoT, and others highlight the objects that are connected to this network. However, most of the definitions concentrate on internet-based connections and acquire real-time data (Kaur, 2021). All of these definitions meltdown to viewing IoT as a pervasive network that connects various sensors with the internet and provides meaningful information. The importance of IoT is clearly explained in the above definition presenting the wide scope of IoT. However, it ignores the quality and capability factors of IoT which are of high importance for creating value to the public, particularly in the sense of smart government, and that is a major objective of IoT (Wirtz et al., 2018b). Being based on this periphery, IoT can be understood as the ability of things to shape on their own, share data and available resources by acting and reacting whenever there is a change in the existing environment by the linkage of wide-ranging grids or networks where these objects are connected. The usage of IoT is exponentially growing at high speed. Lately, the use of IoT network with many associated devices in it has boomed up dramatically. This has resulted in increased expectations among different organizations to create and deliver value to the public (Tohanean and Vasilescu, 2019).

The pervasiveness of the internet caused a significant change in people's life. Likewise, IoT can create a powerful impression on society in upcoming years. Therefore, IoT is recognized as the future generation of the internet. IoT not only saves the available resources and increase the effectiveness and efficiency of the overall system but also generates benefit for both public and private sectors (Qiu et al., 2015b).

IoT framework plays an important role in transforming society because its usage comforts and benefits the citizen in different ways and increases their lifestyle. This paper is limited to using IoT in the water supply management sector.

Water is a precious resource and without it, our lives cannot be imagined. Therefore, its management is very important. If leakage and overflow of the water can be controlled, there will be a dramatic saving of water in any country. By deploying the

Table 2.4: KUKL service area estimated demand and supply of water (Udmale et al., 2016)

KUKL Service Area	**Supply Capacity 2013 MLD1**	**Domestic Water Demand in MLD**				
		2001	**2006**	**2011**	**2016**	**2021**
Baneshwor	1.2	29.6	35.7	43.0	51.8	62.4
Bhaktapur	4.6	11.3	12.1	13.1	15.0	16.4
Chhetrapati	0.5	13.3	16.0	19.3	23.2	28.0
Kamaladi	0.0	4.0	4.8	5.8	6.9	8.3
Kirtipur	3.9	6.7	8.2	10.1	12.5	19.6
Lalitpur	23.7	27.5	32.4	40.1	49.7	63.2
Madhyapur Thimi	13.6	5.5	7.3	9.6	16.3	21.5
Mahakankalchour	55.5	28.9	37.9	50.8	69.5	99.9
Mahargunj	44.5	23.6	30.8	42.1	58.4	82.5
Tripureshwor	3.9	18.5	22.4	27.2	34.4	43.5
KUKL SA only	**151.2**	**168.7**	**207.5**	**261.0**	**337.8**	**445.3**
Valley (including KUKL SA)	-	**183.9**	**224.9**	**282.5**	**366.0**	**481.5**

IoT application and its framework, leakage and overflow of the water can be controlled thereby facilitating online payment based on the amount of water consumed by each household. The amount of water consumed by each household can be monitored online or remotely without using the water meter. The tough task to collect the data regarding water consumed in a different area is reduced and made automatic by using the IoT concept. Table 2.4 depicts the estimated demand for water using BIS (Bureau of Indian Standards) guidelines.

The data as shown in Table 2.4 display the supply capacity in KUKL (Kathmandu Upatyaka Khanepani Limited) service area. To forecast the domestic water-demand, a lot of time and dedication has to be given, and mathematical computation should be done. Nevertheless, efficient usage of IoT makes all these tasks automatic and also reduces the number of manpower needed for data collection jobs. The usage of IoT will benefit not only the citizens but also the government in many ways.

2.16 Theoretical Framework

The technology acceptance model is shown in Figure 2.7. Whenever any technology is developed, the main focus is on its actual use. The use of the system is highly influenced by the behavioral intention like, what factors will strengthen any customer and compel him/her to use the system. The behavioral intention is guided by the attitude of a person.

Some people adapt to the technology as soon as it comes to the market place. Some

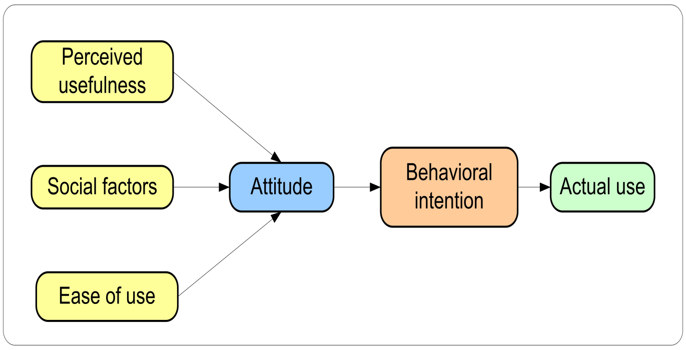


Figure 2.7: Technology Acceptance Model (TAM) (Davis,1989)

people adapt to it after observing how other people are using the new technology. The attitude of any person is influenced by perceived usefulness of the system as people have started to use online payment system which saves time and effort going to the bank and withdraw any amount. Similarly, if the system is easy to use, people tend to use it. So, considerable attention should be given while designing the user interface (UI), to get feedback regarding user experience (UX) and customize the system accordingly. Social factors also help develop the attitude of a person. If some applications are harmful or very useful, the society conveys the similar message. These messages in turn shape the attitude of a person. The attitude can be positive, negative or neutral depending upon the perceived usefulness, social factors and ease of life. Implementation of an IoT framework in several sectors transforms the society from perspective of the technological usage and procedures of works being done. Therefore, the research task related to the survey and interview will be guided by the Technological Acceptance Model (TAM). The sustainability factors, perceived usefulness, social factors, ease of use, attitudes and the behavioral intention of the people can be studied.

CHAPTER 3

METHODOLOGY

The research carried out incorporates scientific method because of the systematic, empirical, and controlled investigation. Framework based on experiment will be used in developing IoT framework, and qualitative method will be used in infrastructure analysis required for implementing smart city. Figure 3.1 shows the scientific aspects of the study.

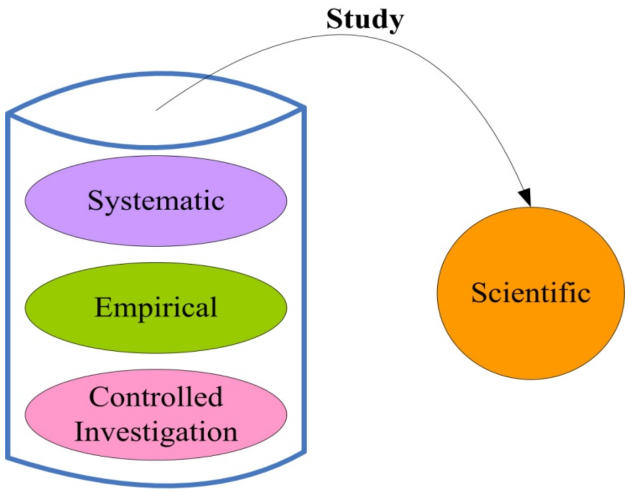


Figure 3.1: Scientific study involved in research

3.1 Research Approach

In order to accomplish the objective of this research; experimental, observation and interview were the approaches adopted which were considered most suitable.

An experiment is carried out and an investigation is done. The independent variable amount of water (the cause) is manipulated and the dependent variable (the effect) in consumption of water and leakage is measured, extraneous variables are controlled by adopting exception handling techniques and moving average method.

As an experiment it has been planned to use a prototype to collect the real time data from the respective household. The experiment as shown in Figure 5.1 helps develop an automatic system to fill and store the water in a home using ultrasound technology. Experiment uses two cylindrical water tanks. Two ultrasonic sensors will be used, one in the bottom and the other in the upper tank. The storage tank (bottom tank) is in the lower position and from this tank the daily usage of water of home takes place. The comparison between the levels of the water of these two tanks will be done to automate switch on the motor. Ultrasonic Sensor1 and sensor2 used in the bottom tank and upper tank considers the mathematical relations that are based on Doppler's effect.

As an observation approach the obtained results are observed. Kathmandu valley has been chosen as a spot to deploy the experiment. The experiment will be conducted for 360 days for 6 spots from in Kathmandu valley. The status of consumption and leakage amount of water in these spots will be observed in all these 6 spots. The number of water supplies all over Nepal will also be observed and the prospects of this research will be analyzed. Besides this the infrastructure required for implementing IoT like Tele-density and internet penetration, Broad band services, Mobile phone penetration, Internet service providers, number of software companies, data centers will be observed.

In this research, interviews will be carried out with the government officials, municipality Mayors, Directors, and some IT and engineering professions to know about the underlying infrastructure and feasibility of smart city. Altogether 23 interviews as a part of qualitative research will be conducted to find out the answer to know where the problem is to establishing efficient smart city.

3.2 Research Tools

This research has three different segments, and the tools used in these three research segments are as follows:

3.2.1 Application platforms used for experiment

The different platforms used for the experimental part of this research are shown in Figure 3.2.

1. Python language (version 2.7) has been used for programming raspberry pi (Version 3B+)
2. Mysql has been used to construct the database.
3. PHP language has been used for building the Web Server
4. React Native has been used to make the mobile application

3.2.2 Method adopted for interview

The following method are adopted to conduct interview:

1. Unstructured open-ended questionnaire was used in direct interview method and also by using telephone survey for distant locations

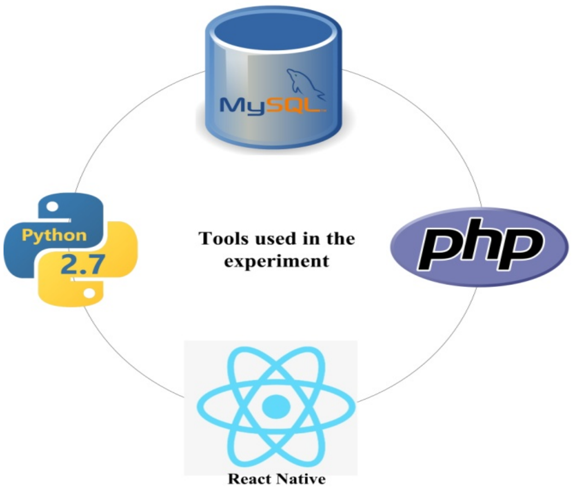


Figure 3.2: Tools used in experiment

2. The populations for this study are the government officials working at municipalities, ministries, and Telecom industries under IT and engineering departments.

3. Convenient sampling technique was used for which Solvin's formula n=$\frac{N}{1+Ne^2}$ was used, and so the sample size of 20 was obtained from the tolerance level of 22% error, Population size (N=322).

3.2.3 Method used for observation

No special methods have been adopted excepts some snaps taken by the mobile phone while visiting the field.

3.2.4 Tools used to develop IoT Framework

Computer Aided System Engineering (CASE) involves software-based modeling tools. Simple tools like whiteboards and some statistical tools like unit regression are used by agile modelers. By comparing different modeling approaches like Model Driven Architecture (MDA), Agile Model Driven Development (AMDD) and Agile Model Driven Architecture (AMDA), any one approach can be used in modeling the system. To develop the IoT framework the following steps are encompassed:

a. Test Driven Design (TDD)

In a TDD, sufficient source code is written to satisfy the test, and thus model is modified time and again.

b. Drawing Tools

Microsoft Visio has been used to draw the realized framework.To ensure the flexibility, modularity and scalability this research will use AMDA approach to develop the IoT framework.

3.2.5 Tools Used for documentation and thesis writing

LaTex has been used for writing thesis. MS-Office word 2016 has been used to write manuscripts of the research, and MS-Office Powerpoint has been used to prepare slides for presentation.

3.3 Experimental Setup and specifications of the components used

Python programming language has been used to program the Raspberry-Pi. The Table 3.1 shows the specific technical details and uncertainty of the devices used in the experiment.

3.4 Survey

The survey based on observation has been carried out to get insights about the prevalent infrastructure to adopt IoT framework in Nepal. Nepal Tele Corporation (NTC), Nepal Telecom Authority (NTA), 28 municipalities of Nepal, Kathmandu Valley Development Board, Kathmandu Upatyaka Khanepani Limited (KUKL), Nepal Drinking Water Corporation (NDWC), and different Government institutions related to this field were visited.

The local administrations in urban and rural areas are regularly working to install CCTVs, smart poles, smart maps, internet, and other ICT infrastructure. According to the survey conducted by Lalitpur Metropolitan City (LMC), strict policies, practicable guidelines, usage of ICT, skill enhancement, and ICT skilled human resources as well as useful and informative websites are the major areas to which the LMC is giving priority. The survey also concluded that, if Nepal government works in these areas, the country will definitely catch the right track to form the smart cities in Nepal (Karki and Dahal, 2020). This research work also considers digging out about the underlying infrastructural status to create smart city in Nepal.

3.5 Interview

Interviews with several IT personnel working in the municipalities and Nepal Government have been carried out. These interviews were helpful to find out the status of available infrastructure, and to get insights, if it is appropriate to implement IoT framework in Nepal.

Table 3.1: Technical specifications and uncertainty of devices used in the experiment

SN	Device	Specifications	Uncertainty
1	Raspberry-Pi	SoC: Broadcom BCM2837B0 quad-core A53 (ARMv8) 64-bit @ 1.4 GHz GPU: Broadcom Videocore-1V RAM: 1GB LPDDR2 SDRAM Networking: Gigabit ethernet (via USB channel), 2.4 GHz and 5 GHz 802.11b/g/n/ac Wi-Fi Bluetooth: 4.2, Bluetooth Low Energy (BLE) Storage: Micro-SD 8 GB used DC power 3v	Overheating problem causes the system to malfunction
2	Ultrasonic sensor	Model: JSN-SR04T Operating voltage: 5v Operating current: 30 mA Quiescent current: 5 mA Resonating Frequency: 40 KHz Measuring range: 25-450 cm Measuring angle: 45-75 degrees Resolution 2 mm Sensor dimension 23.5 X 20 mm X 2.5mm	The sensor cannot measure the distance less than 20cm
3	Water pump motor	Power Range : 0.5 HP to 1.0 HP 1 phase, 2900 RPM Capacity: 30LPM - 2500 LPM Total Head: 6.0 to 50 Meters	
4	Relay	Channel: Single channel Frequency: 315 MHz Voltage: 220 v	Voltage fluctuations hinder the output of the relay
5	Router	External Power Supply: 9VDC / 0.6A Wireless standards: IEEE 802.11n, IEEE 802.11g, IEEE 802.11b Dimension: 7.2 X 5.0 X 1.4 in	
6	Cat 6 cable	Frequency: 250MHz Max Transmission Speed: 1Gbps/10Gbps Distance: 100 m with 1Gbps 37-55m with 10Gbps Number of connectors in channel: 4 Cable Construction: Shielded Connector type: RJ 45	
7	Smart phone for prototype only	Model: Huwawei Nova 3e (Android OS) Model: iphone 8, MQ6L2LL/A, 64 GB (IOS)	
8	Database	MYSQL	Simultaneous user limit to 10000
9	Web Interface	PHP for backend and HTML, CSS and JS for frontend	

To dig out the status of available infrastructure to establish smart cities in Nepal, qualitative interview has been carried out. The survey carried out by National Information Technology Center (NITC) in 2019, shows that there are overall 322 government officials involved in creating the smart cities and using the Solvin's formulae have been used to calculate the sample size. Out of population (N=322), sample size (n=19.42≈20) has been obtained from tolerance level (e) of 22%. The overall methodology of this research task is shown in Figure 3.3.

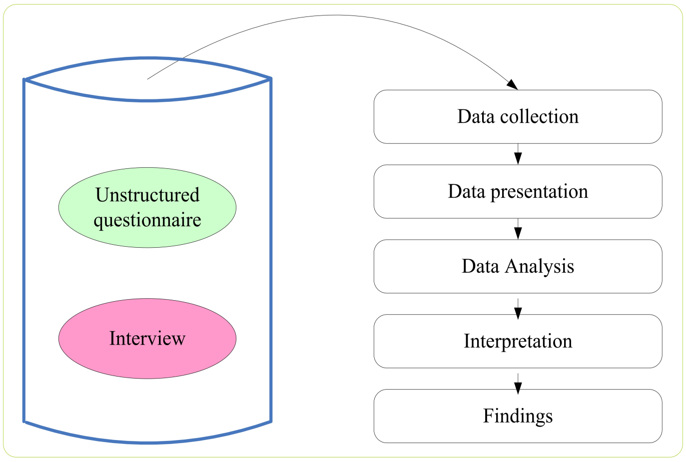


Figure 3.3: Methodology in interview

Kathmandu, Lalitpur, Syangja, Khotang, Biratnagar, Sakhuwasabha, and Jhapa were the districts from which key personnel for the interview were selected. Most of the samples were selected from Kathmandu district because the largest population of the country resides here. Some reviews from experts are also considered to know about the prevalent infrastructure to build smart city. Similarly, group discussion was also conducted to get insights about the infrastructural status in building smart cities. The questionnaires were developed including 16 qualitative questions, and interview was conducted to get the answers of those questions. After the data are collected, the presentation of the data is done using different graphical tools. The next step is the interpretation done from the data regarding the focal point, that is to know the status of infrastructure in Nepal in building the smart cities. Finally, from all these analyses and interpretations, the findings are presented.

3.6 Methodology in an aerial view

The flow diagram represented in Figure 3.4 shows overall methodology that will be followed while conducting the research. This diagram is a blueprint of this research.
From the review of literature, an IoT model is developed. The developed model is realized using a real time experiment. After this, the results are compared with the result of similar studies to validate the framework. Similarly, reliability test is conducted. The

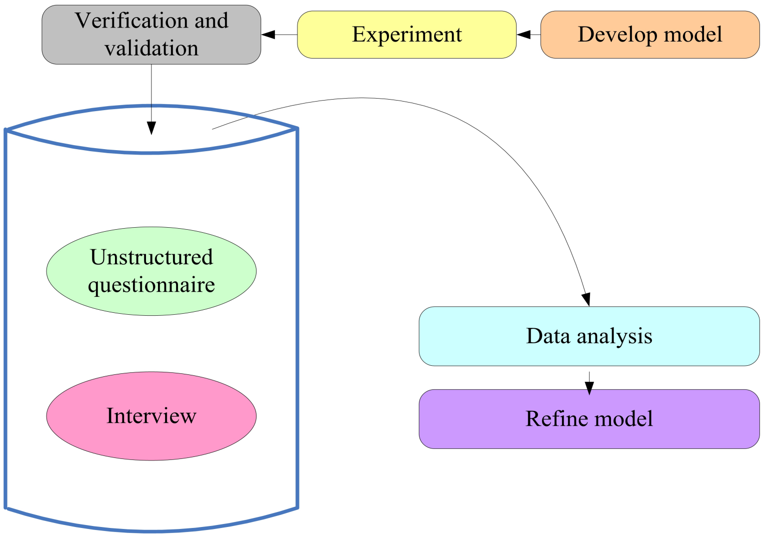


Figure 3.4: Overall methodology

framework is then reviewed by the experts, and feedbacks are obtained, and the models are revised accordingly. Unstructured questionnaire is developed to conduct interview regarding the smart city development in Nepal. The analysis of data based on the output of interview is done. Finally, after discussion with the professors and senior faculties, the model is refined.

CHAPTER 4

DEVELOPMENT OF IOT FRAMEWORK

The major purpose of this research was to develop a generic IoT framework that fits to most of the sectors like water supply, agriculture, irrigation, electricity management and so on. The output of the experiment, mathematical models developed during the experiment, the observation and survey carried out to get insights about the prevalent infrastructure, all of them melt down to forming an IoT framework which is regarded as the major outcome of this research.

The objects connected in the network of IoT becomes intelligent and they transmit information through the internet. The gateway is formed using Raspberry-Pi which helps transmit the information via internet using Message Queuing Telemetry Transport (MQTT) protocol.(Ryu, 2015).

The experimental section of the framework is concentrated more on generating the real-time data. The conceptual section deals more with the management and efficient usage of the data. When the voluminous data are generated from the experimental section at a high velocity, big data analytics is very essential. And servers like Amazon S3 (simple storage service) can be taken into consideration. Similarly, the management of the data can be undertaken by establishing own data center. After the data sets are obtained, the system can be trained to obtain the future values regarding demand and the supply of water. (Gautam et al., 2021) The IoT framework so developed has been categorized under two sections; one is experimental section and the other is conceptual section. Experimental section has been realized from the experiment as shown in Figure 5.1. and conceptual section is constructed based on the concepts regarding what can be done after we get the data from experimental section. Components of each section are discussed below:

4.1 Experimental Section

The experimental section in this IoT framework contains of three units:

1. Sensor and Module Unit
2. Control and Processing Unit
3. Online Application Unit

4.1.1 Sensor and module unit

The sensor and module unit is one of the fundamental units, without which we cannot pronounce IoT. In any IoT application sensor and module plays a significant role. Control and processing unit is dependent on sensor and module unit and online application unit is dependent on control and processing unit. Therefore, if sensor and module unit does not work, the presence of other two units are meaningless. The sensor and module does not only mean the sensors used in IoT applications. The constituents of sensor and module unit are discussed below:

1. **Signal Conditioning**

   The outputs of the sensor are analog in nature and it needs further processing to make the analog output to digital, otherwise the prevalent digital computers or digital system cannot be able to take the analog output of the sensors as a digital input.

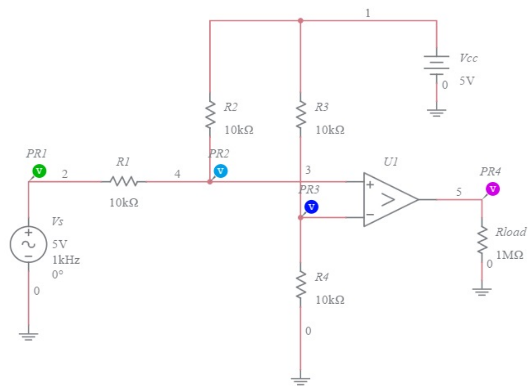


Figure 4.1: Sine to square wave converter (Aihsan et al., 2019)

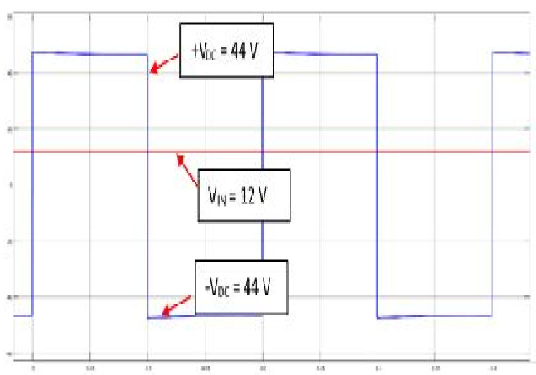


Figure 4.2: Square wave obtained from the circuit (Aihsan et al., 2019)

Figure 4.1 and 4.2 depict the square wave conversion from sine wave. This is important because microcontroller cannot process analog signals. It is not only converting the signal from one form to another but also amplification of the signals carried out in signal conditioning stage. In most of the cases the outputs of the sensors are obtained in millivolt and in this case most of them use biomedical instrumentation amplifier or operational amplifier to amplify the signals in volt range. In a nutshell, signal conditioning stage deals with voltage and current limiting and it uses anti-aliasing filter. However, these days in most of the transducers these features are inherently included to ease the users. In the experimental setup, ultrasonic sensors has been used. The sensor first transmits the ultrasonic signals and detects it. Biomedical instrumentation amplifier INA102KP has been used to amplify the signals in order to be properly sensed at the receiver.

2. **A2D conversion**

   The analog to digital converter is used to convert the analog signal obtained from the signal conditioning unit to digital. This is an important stage because microcontrollers and modern digital computers only understand digital input, so that the further processing can be done. ADC 0804 and ADC 0808, helps converting the analog output of four and eight sensors to digital respectively. These days microcontrollers like Arduino and Raspberry pi have ADC embedded within the chip and we just need to write some few lines of code to use it. In this study we first transmit a signal of 10 microseconds pulse from the Raspberry Pi by using ultrasonic sensor. It is then read by the sensor through its trigger pin and it then generates an ultrasound wave. The wave is again received back as an analog signal and the time for the signal propagation is sent to the Pi as an echo pulse in digital form. Thus the conversion task is performed by the adc chip embedded in Raspberry pi.

3. **Digital Signal**

   The result obtained from the A2D converter is a digital signal which operates the overall system. The digital signal is used to represent the data as a sequence of the discrete values taken at a given time. The digital signal is also quantized and encoded amplitude signal. The input to the ultrasonic sensor is a digital high for a duration of 10 microseconds. In addition, the sensor returns time as a digital pulse which is then post calculated to compute the water level.

4. **Sensor and its placement**

   The placement of sensors matters in a way that if it is not positioned well, we cannot obtain precise reading from the sensors. Those sensors that work on light waves, sound waves, infrared wave, Bluetooth consider their position as critical. Fairly, good knowledge should be there for IoT application developers regarding the placement of the sensors. In the experimental setup, the sensor needs to measure the water level.

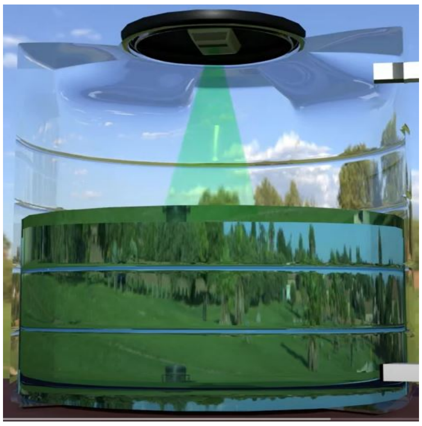


Figure 4.3: Perpendicular alignment of the sensor in the water tank

Figure 4.3 depicts the perpendicular alignment of the sensor module. If it is not aligned perpendicularly, then the reading might be flawed. Therefore, the sensors have been placed on right on the top lid. In case of specific use, the sensor is best if it least interacts with the water which is possible using a number of ways. Since the experiment deals with water the need was waterproof sensor. The best one available is waterproof ultrasonic sensor.

5. **Exception handling**

   Sometime one of the outputs of the sensor gives erroneous value and this might lead to malfunctioning of the system, and there might be cases that introduce heavy loss. Therefore, some mechanisms and protocols should be followed to ensure, sometimes even if the sensor gives wrong result, the module should be able to handle it. These days the module attached with the sensors, handles such exception. Even while programming the microcontroller, exception can be handled, which will be discussed later in control and processing unit. One of the most important factors while working with hardware is the error tolerance. To address this issue, a lot of techniques have been tried and the best technique exploited the fact that water level cannot change rapidly in a tank. Considering this a threshold difference measurement of each consecutive readings have been taken. An average of 20 readings was taken while also ensuring that each of the consecutive reading differ from the previous under a given threshold.

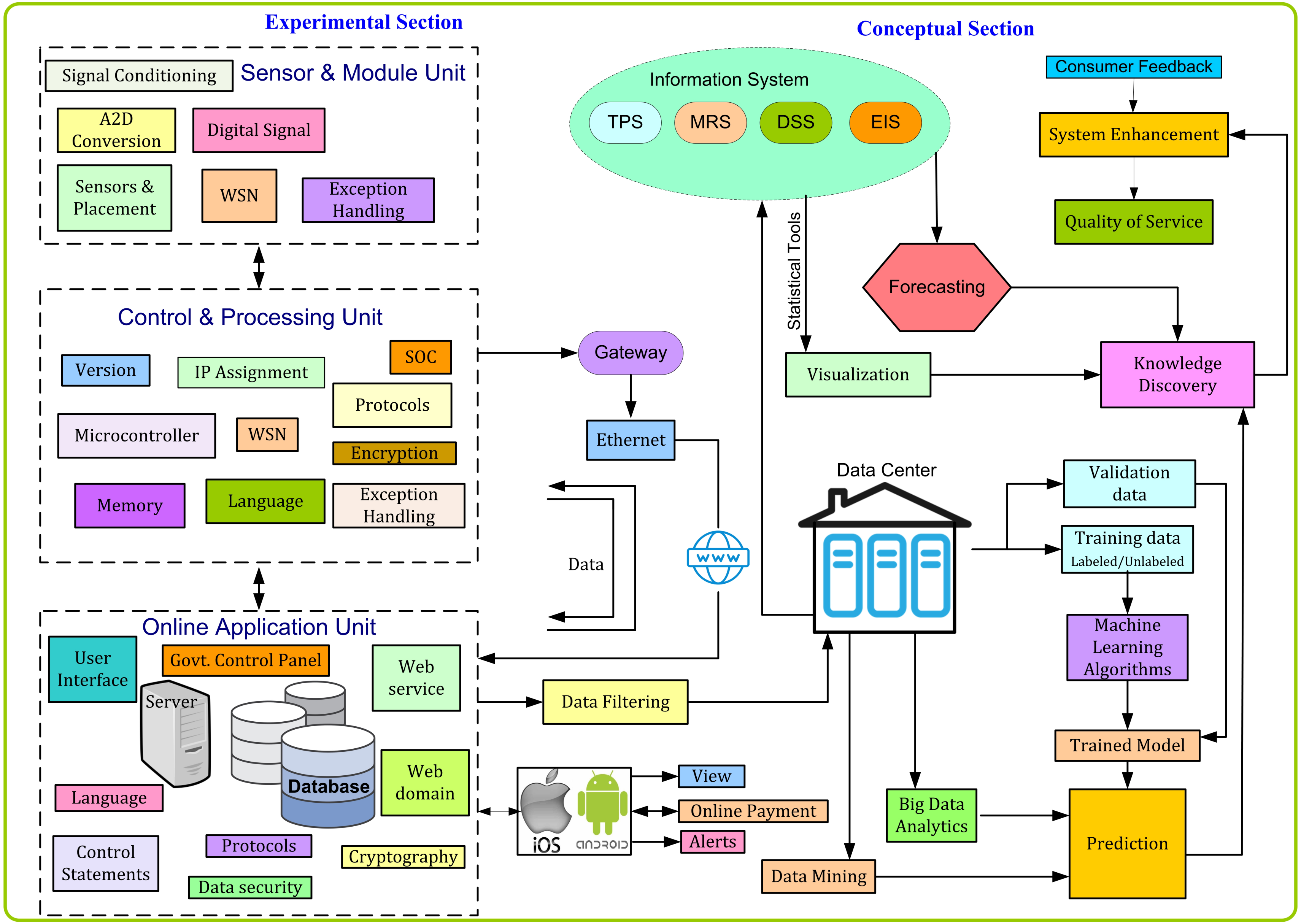


Figure 4.4: IoT framework concentrated on technological layer

6. **Wireless Sensor Network (WSN)**

   Wireless sensor network (WSN) does not require any infrastructure and can configure on its own that can monitor temperature, vibration, pressure, motion, humidity, distance and have ability to transfer these data through this network to a main sink. This unique capability of the network can identify the sensor which is not functioning well and even in that case the system does not have to stay idle because of the alternatives available in this robust network. Hundreds to thousands of sensor nodes are there in WSN and the key feature is they are manageable in their own because they communicate, collaborate and cooperate during operation. A WSN is equipped with radio transceivers and low power computing devices. Global Positioning System (GPS) can also be applied in each sensor nodes to know the location and position of each sensor in the network. WSN helps in making the IoT systems more efficient and scalable as well as handle the queries sent from the control cite. In the experimental part of this research, sensors are limited to a household purpose only. Two sensors in each household have been used, one of which is connected through a LAN. The LAN used is ethernet based but it can be easily replaced with any wireless medium.

4.1.2 Control and Processing Unit

The digital output obtained from the sensor and module unit acts as an input to control and processing unit. The overall manipulation of the system is done in this unit. The heart of any IoT system is microcontroller and the overall programming required in embedded system is done here. The constituents of control and processing unit are discussed below:

1. **Microcontroller**

   In fact, the heart of any IoT system is microcontroller and it controls the overall system like sensors, peripherals, and other electronic components embedded in the system. There are different types of microcontroller available in the market place, Table 4.1 shows the type of microcontrollers and its features:

Table 4.1: Availability of Micrcontrollers and their features

SN	Microcontroller	Features	Connection to internet
1	8051 and 8052 family a. AT89C51 b. AT89C52 c. AT89C55 d. AT89C55WD	–Reduces the circuitry as many logical and control features are included in the chip –Low Cost –Difficulty in loading the HEX file in the microcontroller	GPRS interfacing is required
2	AVR a. ATMEGA 8 b. ATMEGA 32	–Reduces the circuitry as many logical and control features are included in the chip –Low Cost –Easy circuitry to load the HEX file in microcontroller	GPRS interfacing is required
3	Arduino a. Arduino RS 232 b. Arduino Uno c. Arduino Robot d. Arduino Lillypad	–Reduces the circuitry as many logical and control features are included in the chip –Cost is higher than 8051/52 and AVR family microcontrollers – No circuitry required to load the HEX file in microcontroller as it is connected to the computer to load the program	– GPRS interfacing can be done –Separate Ethernet should be mounted on the Arduino board to connect it to internet
4	Raspberry Pi a. Pi 1 b. Pi 2 c. Pi 3 d. Pi 0	–Highly reduced additional circuitry for the embedded system –The cost is higher than any other microcontroller –Size and Memory of RAM varies according to the types	Can directly be connected to the internet, no extra board or component is needed.

Being based on the requirement and budget, the type of microcontroller can be chosen to implement IoT for any sector. Raspberry Pi 3B+ has been used in this research because it fulfilled all the requirements to carry out the experiment. Pi not only allows to interface the data and send it to server but also store it locally. The locally stored data worked as a fail safe backup so that if in case the data is not sent correctly to the server, it can be retrieved anytime. Likewise, it opened doors to multimedia which has been implemented in the experiment.

2. **System on Chip (SOC)**

   This type of chip integrates most of the electronic components and of computer. Like microcontroller it also has input output ports, central processing unit (CPU) and memory. This type of chip is more common in recent smart phones. The major difference between any microcontroller and SOC is in the size of the chip and power requirement. However, when the size and cost matters SOC can be used, but one has to cope up with the complexity in using it by himself/herself. The Pi used in this research has a Broadcom SOC with 1.2 GHz 64-bit quad core ARM Cortex-A53 processor. It allows to run multiple processes so that it can be programmed to both; control our sensors as well as manipulate and transmit the data.

3. **Versions**

   Different versions of microcontroller and programming language matters while developing IoT system. It is because different versions of hardware and programming platforms have different features. This is also the reasons that many SOC and Operating system developers like Android and IOS regularly update the versions by adding the features and removing the bugs associated with the system. In this experiment Python programming P2.7 version and Raspberry Pi Version 3B+ have been used. The choice of these versions have been driven mostly by popularity and abundance.

4. **IP Assignment**

   The task of assigning Internet Protocol (IP) address assignment to the prevalent sensors in IoT applications is interesting. Actually, there are no such guidelines and protocols to assign IP address to the sensors. But again, we need to assign IP address to the sensor nodes in IoT framework for smart city in order to connect the system to internet. The concept of IPV6 is burgeoning these days because critics are saying that IPV4 is insufficient to allocate IP address for all the sensor in the network of IoT applications. The Table 4.2 shows the number of available IP address in IPV4 system:

Table 4.2: IP address in IPV4 system

S.N	**IP class**	**Available address**	**Number of sensors**
1	C	2^8-2=254 Adresses	254
2	B	2^16-2=65534 Adresses	65534
3	A	2^24-2=16777214 Adresses	16777214

The IP addresses listed in the Table 4.2 can be assigned in a single IoT system. Identification number can also be assigned to individual sensor present in the system. There is no chance that IP address be overlapped because it is controlled by the SOC or microcontroller and the communication between sensors is possible only when unique IP addresses are assigned to the sensors. In this experiment, two sensors have been used and IP address is assigned as shown in Figure 4.5.

Though the IP address for master and slave differs, the port address for both of them should be identical. This is the crux that has to be followed for flawless communication. In the experiment carried out in this research, setting up the IP of the master and slave was done which then shared a common port. The port used is not fixed and can vary based on each connection but it is ensured that both the devices communicate using the same port during the connection.

Figure 4.5: IP address assignment to Master and Slave in IoT

5. **Language**

   The language refers to the programming language. Those were the days (90's) when programming in a microcontroller was done using assembly language. After some years, C programming could be used ($\approx 2000AD$). The C programming language made the system developers easy to work with the embedded system. These days C, C++ and python programming language has been popular. In this experiment Python programming language is used for developing embedded system required for IoT. Python has been chosen because it is one of the popular language to program the Raspberry Pi.

6. **WSN**

   In this section the important thing to disseminate is all the sensors integrated in WSN are controlled and managed by the control and processing unit. Some sensors may not function well or sensor may stop working, in such a case, this section manages to let another sensor carry out the work if possible, otherwise, gives an appropriate message to the concerned ones.

7. **Protocols**

   The protocols in IoT systems are generally related to the hardware or software. The communication protocols, IP protocols, database design protocols, front end design protocols, Web development protocols as well as sensor interfacing protocols should be followed. To ensure the flexibility and scalability, network and communication protocols have been used. The sensor uses serial communication with the Raspberry Pi and the Pi communicates with other using IP. In a like manner Hypertext Transfer Protocol (HTTP) is used to communicate with the server.

8. **Memory**

   The memory of the microcontroller is just limited to write lines of codes and store some data generated by the sensor before sending to the server in IoT applications. The size of RAM in microcontroller matters in speedier operation of microcontroller. The scalable server is the present-day demand because in case of IoT the data is generated everyday in huge amount and the interest of many concerned authorities is to store the data in the private cloud offerings. When the Raspberry Pi uses a 16 GB memory card as its secondary backup, it uses 1GB RAM for primary. The data stored in the memory of microcontroller is then sent to the server which stores all the incoming data from multiple IOT networks.

9. **Encryption**

   On the one hand the transmitted data might be vulnerable from the security point of view, on the other hand it might be equally valuable. To ensure the data security encryption technologies play a significant role. Encryption hides the original data by adding something to the original data, the added data is called as secret code and more often regarded as a key. This key is available to the user in the receiver side, and others cannot use it. The process of encrypting and decrypting is called as cryptography. The core concept of encryption is converting the plain text into cipher text and only authorized person can decipher the text. There are different types of encryption method like Data Encryption Standard (DES), 3-DES, Advanced Encryption Standard (AES), Diffie-Hellman, Rivest Shamir Adleman (RSA) and so on.

10. **Exception handling**

    In this unit we deal about the programming aspects of exeption handling. Try, Catch and Throw is the major gist of exception handling. Whenever, unusual data is received as an output of the sensors, we try to search this, catch it and throw such output from the system. However, it might not be possible for all systems to throw an unusual output generated by the sensor. In such a case average of twenty values can be taken as an input, this is what has been done in the experiment related to this research.

4.1.3 Online Application Unit

After all the processing are done, the data from the control and processing unit are transmitted to the cloud through the Ethernet, in the appropriate web domain specified by the company who is authorized as an IoT developer. In this unit the processing and operations done in web are discussed.

1. **Gateway**

   Gateway acts as an intermediary between the control and processing unit and online application unit. The data to the online application unit is transmitted through the gateway, which just acts as a memory buffer and it is located in the microcontroller or SOC.

2. **Ethernet**

   Ethernet is a system used for connecting many computer systems and create a Local Area Network (LAN) with certain protocols associated to pass the data and avoid the simultaneous transmission of data by more system at the same time. In an experiment used in this research the ethernet board is mounted in the Raspberry Pi. Ethernet has been used to connect the Raspberry Pi with the LAN which allows to access to the world wide web.

3. **User Interface**

   The users in IoT always demand a simplistic view of essential data only. The place where the essential data are displayed in web browser. Different programming languages are used to design user interface, PHP, Dot Net and C sharp are some popular web development programming languages. In this experiment React Native and Redux has been used to create the user interface. The user interface is shown in Figure 4.6.

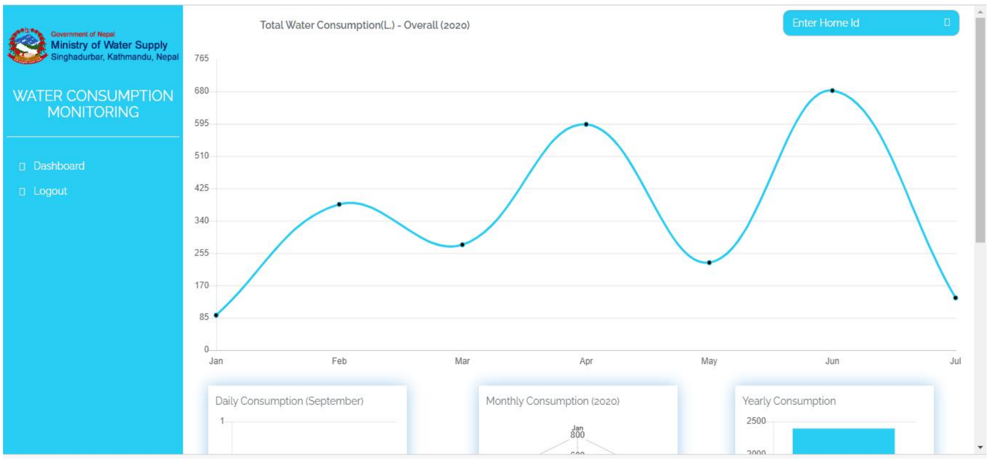


Figure 4.6: User interface of the experiment

4. **Web Domain**

   Web domain is used to identify particular service or a company and sometimes it might be individual as well in the internet. When the domain name is typed in the URL bar, it sends a request to Domain Name System (DNS). This is like a gigantic book that lists overall IP addresses and the related domain names. The process how domain is forwarded is:

   (a) Server looks for the name servers associated with the domain name.

   (b) The hosting company is in charge of managing the name servers. It will forward the name server request to the server where the files of the website are stored.

   (c) The web server will accumulate the information that has been requested and sends it back to the browser. A lot of process goes behind the scene to display any content of the website. At the beginning, the web server was hosted locally so that IP was used instead of the domain.

5. **Web Services**

   Billing services, payment services, email services, notification services are provided over the web these days. While providing the web services, one system may connect with the other system. This mostly occurs while making payment through internet. To provide the web services, serving web document like HTML, JSON, XML are employed. In web services, web technology like HTTP is used for transferring machine readable file formats like XML and JSON. The experiment plans to incorporate the mailing service as well as API based messaging service for notifications about the bill and schedule along with the various warning generated by the system.

6. **Language and versions**

   Web development programming language is one of the core component of online application unit. Dot Net, C Sharp, PHP are some popular programming languages used for web development. In the experimental part of this research, PHP has been used for web development. The version of programming platform also matters in terms of added features in programming. This not only makes the programmer easier but also helps to fast developing the system. PHP has been used for this experiment because it is easy to develop and deploy. Also, React is used in frontend.

7. **Protocols**

   There are also some sets of rules that have to be followed in the online application unit. The protocols here are about the internet communication protocols (ICP). These protocols are published by Internet Engineering Task Force (IETF). The IEEE (Institute of Electrical and Electronics Engineers) handles wireless as well as wired networking. International Telecommunication Union Telecommunication (ITU-T) handles telecommunication protocols. The rules set in these protocols should be adhered while developing the IoT systems.

8. **Server and cloud computing**

   The location of the server can be anywhere, but should be able to provide 24X7 services to the client. A single server can provide services to multiple clients. Cloud storage and cloud computing are in much demand these days and most of the institution working for IoT are taking private cloud services to ensure the security of residing data in the server as well. With the huge surge in data from the IOT, it is important to store, analyze and host this data in real time as well. Cloud services allows us to achieve this with a 100% uptime and helps us not to miss any data at all.

9. **Control Statements**

   In online application unit the control statements in the form of queries are sent from the control site to remote site. These queries request for the data as per their request. To perform this function the queries are sent to the server and the system fetches the data in the database and returns with the required data. The individual Pi's can also be controlled from the control site, if it has to be done. For this, each of the Pi is programmed to read control statements from the server so that we can stop the working in case of delayed payments or other such emergencies.

10. **Data Security and Cryptography**

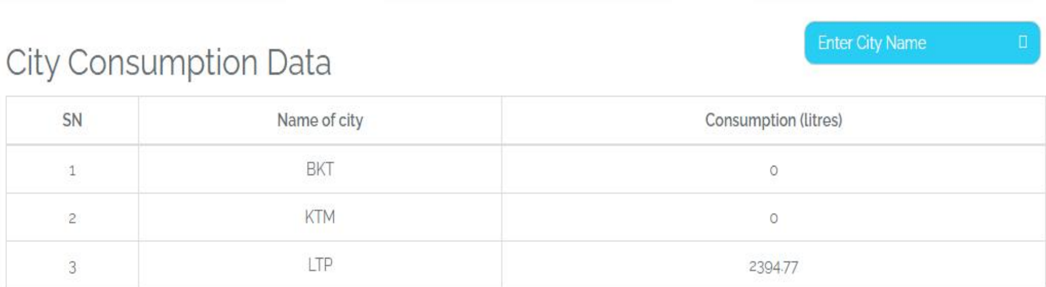
    Data is considered to be the pearl of any IoT system and to ensure its security is the responsibility of the IoT service provider. Intruders may enter into the system and hijack the data, this can become one of the worst situations, so, to ensure the data security the cryptographic concepts are applied to the system, MD5 encryption in the database and RSA, Diffie Hellman, DES, 3-DES and AES methods can be used to convert the plain text to cipher text in transmitting side and key can be provided to the real user of the system so that cipher text can again be converted to plain text. Data security is important which is enabled by a lot of Cloud services now a days.

11. **Database**

    The data in database should be stored in such a way that it becomes easy to search, view, create, update and delete. MYSQL, ORACLE and Go Lang are some platforms where database can be designed. In the experiment of this research MYSQL has been used to construct the database. Database Administrators (DA) should handle the database system. MYSQL with multiple tables has been used to store data such as location data, user details, consumption data and leakage data. It is controlled using Python locally and PHP at the server end.

12. **Government Control Panel**

    If the IoT system incorporates the basic necessities like water and electricity, then it has to record the data of the citizens living around. Therefore, such IoT systems should be equipped with the panel incorporating control measures that can be taken to monitor and control the system. The government control panel designed in this research is shown in Figure 4.7.


City Consumption Data

Enter City Name

SN	Name of city	Consumption (litres)
1	BKT	0
2	KTM	0
3	LTP	2394.77

Figure 4.7: Government control panel

13. **Data Filtering**

    All the data stored in the database might not always be significant for analysis. In such a case, only requested data are transferred to the data center, or sometimes all the data might also be important. Therefore, data filtering is done at experimental section before passing the data to conceptual section. For this, various filters can be implemented based on the queries passed. We can view the data of individual household alone or entire cities or provinces.

14. **Data in mobile applications**

    Users in IoT system desire to view the data of their individual identity. By viewing the data, they can take necessary actions like making online payment of the bill amount, or pushing some alerts to the user's cell phone via the Android or IOS application.

4.2 Conceptual Section

The conceptual section in this IoT framework begins right after getting the data from online application unit. This section is entirely based on what analysis and study can be done from the data obtained at data center. Voluminous data is obtained from the online application unit which is essential in managing and using these data. Each of the components shown in IoT framework under conceptual section is described below:

1. **Data Center**

   The filtered data from experimental section is migrated to data center. This is also regarded as the repository of data and once we have data, analysis can be done to find the cause of any problem. Establishment of several data centers can be decided by the government if it is deduced that a single data center is not sufficient. It's plausible to note that the government should establish the data center not by natural or man-made boundaries of the nation but based on the demand.

   The features of a Data Center are summarized as follows:

   - High Class Computing Framework
   - Storage nexus (SAN/NAS)
   - Fast LAN
   - Multilevel Security
   - Fast web connectivity
   - Around-the-clock technical support
   - Multi-tier recurring power alternatives
   - Air conditioning facility
   - Fire awareness and control mechanism

   Only providing the facility to store the data is not enough for data center. Data center should also focus on the security of stored data. The data center also deals with Disaster Recovery Planning (DRP) and Business Continuity Planning (BCP). Therefore, Disaster Recovery (DR) site is essential for data center to ensure DRP and BCP. It is almost impossible to imagine implementation of IoT without an efficient data center.

2. **Big Data Analytics**

   The data from the data center can be extracted to perform big data analytics. The three things addressed by big data analytics are volume, variety and velocity. Recent usage of big data analytics means to perform predictive or user behavior analytics. Efficient analysis of different data sets can find the new correlations to spot out the business trends. Xplenty, Knime, MongoDB, Datawrapper, Lumify and Apache Hadoop are some tools used for big data analytics.

   Big data analytics can be used for radical change and governance of the cities with the aid of available mountains of data which provides a more jaded, wider range of understanding as well as control of chaos in urbanity; this also contributes to making the city smart (Silva et al., 2016). Managing and controlling water resources are easy with IoT based water monitoring system. It is fitted with a camera that takes an image of a traditional water meter and predicts the reading by calculating the angle of Dial pointers in the image (Chang et al., 2019). WiFi enables communication that can translate data from low-power sensors. However, collecting event-driven upload of data from numerous low-power sensors with low latency can be challenging. Nodes are generally scanned by access points in WiFi to schedule transmission times of the uplink and that is a major cause of introducing large latency in the system (Kim et al., 2015). The important data should only be transmitted through the WSN intersection points because of the limitation in power supply at these nodes. This not only speeds up the network performance but also is energy efficient (Pinto et al., 2015). The future of IoT is not just a theory but a practical requirement. European directive for energy efficiency improvement calls for IoT with a similar capacity that can be integrated with their power grid. On the one hand, these devices will monitor problems and automate solutions at a much larger scale and, on the other hand, they will generate enough data on the complexity of management of a city that can be used in planning a smart city (More, 2019).

   The experiment carried out in this research generated huge amount of data from the IoT application. The collection of data was reduced at the server by buffering the data locally and sending them in bulk but still, the velocity at server was limited. The data is generated at a high rate at the sensor level.

3. **Data Mining**

   Data mining refers to the technique of uncovering the hidden arrangements or cognition from an abundant volume of data. The process of data mining is executed after performing two prerequisite steps mentioned as follows:

   (a) Data Extraction, Transformation and Loading (ETL)
   (b) Data Warehousing

   Data mining is also known by different names like knowledge discovery in databases(KDD), knowledge extraction, data analysis, pattern analysis, data archaeology, data dredging, information harvesting , business intelligence, etc. Various data mining implements are Python, Kaggle, Rattle, Orange, etc.

   Data mining is considered to be a very handy tool in different business and government firms working in the establishment of nationwide IoT infrastructures. This helps to develop intuition about various factors such as the consumption rate of water and pattern of consumption of any city. These facts further assists them in the decision making process.

4. **Information System**

   Data and information are the core foundation of any business and organization and hence need to be handled and stored carefully. Information systems have a lot of benefits in IoT as it enables efficient operation of business/organization, economic growth, business globalization, etc. It also helps increase the competition with the help of data available online.

   The four components of the information system are Transaction Processing System (TPS), Management Reporting System (MRS), Decision Support System (DSS) and Executive Information System (EIS). TPS is necessary for processing data that are needed for operation. Daily consumption and leakage pattern can be useful for TPS. MRS is necessary for producing results in certain time intervals. It is particularly designed for an authority designated for a certain functional work within an organization. Information regarding monthly consumption and leakage amount of water can be useful in constructing MRS. DSS is needed for making collective decisions based on available data. The surplus amount of water in one area can be redirected to area where there is deficit amount of water. This type of information is helpful for constructing DSS. Long term planning being based on the consumption and leakage amount of water can be done using EIS which is important for senior executives and board members.

The information system of a certain organization can strengthen the relationship between an organization and its suppliers, business partners, customers, etc as information systems can connect all of them together for better coordination.

5. **Forecasting**

   On the basis of the fact obtained from an information system, different statistical analysis can be done like correlation, regression etc. Historical data is the major basis for predicting the future values. The consumption amount of the water in a particular society can be forecasted by using the information system. Regression can be used for forecasting by using historical data. Employing such techniques, we can forecast the usage of water in each household or in the entire groups so that we can prepare for future circumstances and help address problems before they occur.

6. **Trend Analysis**

   The consumption amount varies with time. In some seasons the consumption is higher whereas in some lower. The fact provided by an information system helps to view the trend of consumption. Statistical analysis from the data stored in the data center can also be done to analyze the trend or time series operation can be performed. This analysis has a meaningful impact on constantly maintaining the quality of service. We can analyze the trend in the current data and find out various aspects of the upcoming future.

7. **Machine Learning**

   Chunks of data are available at data center transmitted from experimental section and these can be obtained on the basis of season, year, month, day and so on. Machine learning algorithms/models can be applied to this system and the end result is definitely predictions, estimations that aids in taking essential decisions. Training data set and trained model are prerequisite for any machine learning algorithm and they are discussed below:

   (a) **Training data set**

   The data sets used in the learning process are training data set. An algorithm should be made to learn from the available data and to make predictions or decisions by building some models. As it is known that classifier has better prediction accuracy, this algorithm can be used to predict the demand and supply in an IoT system. Supervised learning can be used to estimate the supply and demand being based on previous input output relation. If the data set (Supply based on month) are available classified on province and city, these can be considered as training data set. Huge volume of data available at data center can be used as the training data set.

(b) **Trained Model**

Model trained with voluminous data can understand and generalize in a better manner. Whenever there are diverse or say varieties of data, then in such a case generalization can make good predictions it is not discriminated towards the data it was originally trained. Producing a model encompasses the following steps:

i. Collection of appropriate data.
ii. Process the data in order to train the model.
iii. Train the model.
iv. Evaluate the developed model.
v. Host this model.

There are several methods to deploy the model; the model can run on an IoT device for learning.

(c) **Prediction**

The end result of all machine learning algorithm is a better prediction by the system itself. When the system (machine) learns by itself, obviously the manual task is reduced to a great extent. This prediction result can be used to automate the system without any bias.

8. **Knowledge Discovery**

Irrespective of the data type whether it is structured or semi-structured or unstructured, the process of extracting meaningful insights from the available data is the major gist of knowledge discovery. The forecasting based on the information system, the trend analysis done by using statistical tool and the prediction done by the system itself after applying machine learning algorithms can be used to discover the real knowledge about an IoT system.

9. **Consumer Feedback**

The end users of any IoT framework are customers. Their satisfaction entice them to use the system. Therefore, the feedback of the customers are very valuable to enhance the IoT framework. Regular feedback are key to know what needs to be modified or added in the existing system.

10. **System Enhancement**

The recommendation obtained from the knowledge discovery unit and the feedback of the consumer can also be considered while managing the configuration as well as different versions of the available IoT system. This block of IoT framework is essential to ensure the Quality of Service (QoS) to the citizens. This allows the system to improve with the surge in users as well as develop new technologies based on the need as well as market trends.

11. **Quality of Service (QoS) to Citizens**

    Though all the components in the IoT framework are working efficiently, if the feedback is not considered while developing the newer versions, the overall system can fail because of the reason of not understanding the real need of citizens. So, their reviews are most in the future development and improvement of the system.

CHAPTER 5

RESULTS AND ANALYSIS

5.1 Realization of Developed Framework

The research work has used full-on experiment to realize the experimental section of the developed IoT framework. The experiment as shown in Figure 5.1 helps develop an automatic system to fill and store the water in a home using ultrasound technology. Experiment uses two cylindrical water tanks. The Local Area Network (LAN) cat6 cable has been used for aiding communication between upper and lower tanks. Raspberry-Pi is used for networking and controlling the sensors. Two ultrasonic sensors are used, one in the bottom and the other in the upper tank. The storage tank (bottom tank) is in the lower position and from this tank the daily usage of water of home takes place. The comparison between the levels of the water of these two tanks is done to automatic switch on the motor. Ultrasonic Sensor1 and sensor2 used in the bottom tank and upper tank considers the mathematical relations that are based on Doppler's effect.

5.1.1 Working Mechanism

The mathematical models are developed empirically during the study period. For the overall system, a mathematical model can be expressed as in Equation (1).

$$Level\ of\ Water(W_L) = L - (0.5 * V_s * Time)............................(1)$$

Where, L represents the length of the cylindrical tank and V_s represents the velocity of sound that equals to 330 m/s. Calculations are done in both the tanks and comparison is carried out. We again assume W_U and W_B as the water level in above tank and bottom tank respectively. Based on the condition of water level in these two tanks motor is switched on. The condition is mathematically written as ,W_B>30 cm and W_U<20 cm. No operations are carried out in other cases. However simple voice message is given to the user as "There is no water in the bottom tank" in their respective cell phone in case if W_B<25cm. These are just about automating the water in both the upper tank and lower tank. This application has another significant impact to controlling the overflow of the water. The overflow of water in each house in Nepal and India is one of the most serious and common issue.

The overflow of the water occurs when the consumers forget to turn off the motor and water is supplied from the tank which is in the bottom to upper. If this overflow could

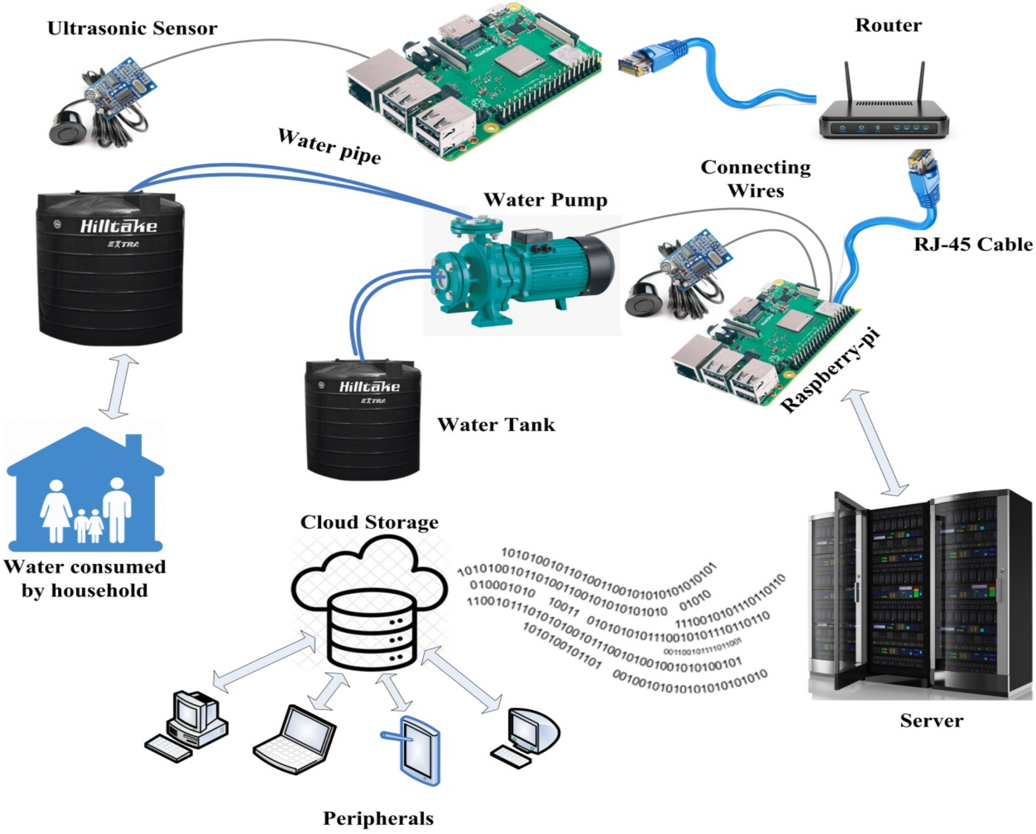


Figure 5.1: Experimental setup

be controlled, huge volume of water in the entire province or country could be saved. The technical specification of the devices used in the experiment is shown in Table 3.1. in chapter entitled Methodology

The amount of water consumed by each house can be calculated by using the following relations:

$$CL_{House\_number}^{Motor\_on} = \pi r^2 \sum_{t=0}^{24\ Hrs} (W_L - W_L^{'}) \quad litres/day............(2)$$

$$CL_{Day} = CL_{House\_number}^{Motor\_on}..(3)$$

Here, CL represents the consumption level. Water level in the lower tank is W_L and new or changed water level in the lower tank is $W_L^{'}$. CL represents the amount of water consumed in 24 hours in a single house and r represents the radius of the cylindrical tank. Data is stored in individual database that is remotely located and can be accessed by the house owner or the authorized government officials. Government agencies may use the following relation to estimate the bill amount (BA) of a month.

$$BA = \left(\sum_{Day=1}^{30} (CL_{Day}) \right) * \frac{Rate}{Volume} \quad Rs......................(4)$$

Here, Rate is the price charged per unit volume by the government or related departments for the consumption of water. This BA is then sent to individual cell phone of the consumers; Rupees(Rs) is the currency of Nepal. If the government or say Drinking Water Corporation wants to know how much water has been consumed this year by the city, then the following relation is used:

$$CL_{Year}^{City\_Name} = \sum_{House\_Number=1}^{N} \left[\sum_{Day=1}^{365} (CL_{Day}) \right] ....(5)$$

similar calculations can be done to obtain the consumption status of any state using,

$$CL_{Year}^{State\_Number} = \sum_{city=1}^{N} CL_{Year}^{City\_Name} ....(6)$$

Eventually, the overall consumption of water in a country where there is reservoir tank can be discovered using the following relation:

$$CL_{Year}^{Country} = \sum_{State=1}^{N} (CL_{Year}^{State\_Number})..............................(7)$$

Here, N represents the number of states in any country.

Six different spots were considered for this study and the experiment as shown in Figure 5.1 was conducted in one house per spot. The experiment was carried out for 360 days in Kathmandu. No flaws were discovered during the experimental period. Until 360 days there was no overflow of the water. Members of the house did not have to bother regarding the effort and time that was required to switch on and off the motor.

The data of the consumed amount of water was sent to the server and in the unusual condition, an appropriate message was sent to the user. Using this IoT application, water supply corporation can cut the water supply line of the house that does not make the payment on time. Similarly, leakage of water in each house can be noticed by using this IoT application. The algorithm to identify the leakage of water from the house has also been developed as follows:

Step 1: Continuously monitor the volume of water in tanks in the time span of 10 seconds.

Step 2: Check the current volume with the previous volume of the bottom tank when the motor is off.

Step 3: If there is any deviation, enable the interrupt and notify the user.

Step 4: Compare the current with previous water volume in the upper tank at night time for a period of one week.

Step 5: If there is a constant deviation for each day, enable the interrupt and notify the user.

The reading is done at night time because if constant amount of water is consumed by any household from 2:00 AM to 3:00 AM for a week then it is certainly a leakage.

The difference of water level (i.e. $0<\Delta W<0.01$ m) is considered as insignificant case (LR=0) and no operation is performed. However, the value of $\Delta W>0.01$ m, indicates that there is leakage (LR=1) and special notification is given to the user. Most strikingly, it has to be noted that the algorithm for leakage monitoring is done at the night time for the only reason that the motor does not get on at that time.
Similarly, the amount of leakage can be calculated by using the similar equation as that was used for finding the consumption level.

$$Leakge^{Volume}_{House\_number} = \sum_{t=0}^{24\ Hrs} (W_{Leakage} - W^{'}_{Leakage}) \quad litres/day..........(8)$$

$$Leakage_{Day} = Leakge^{Volume}_{House\_number} \quad litres............................(9)$$

The leakage amount of water can be known by using equations (8), (9), and (10).

$$Leakage^{State\_Number}_{Year} = \sum_{House\_Number} \left[\sum_{Day=1}^{365} (Leakage_{Day}) \right] ....(10)$$

The above equations are used only in the night time. So, it might be interesting to know how the volume or amount of leakage can be known for 24 hours. As presented in the algorithm above to find the leakage, unitary method can be used to generalize the leakage after knowing the leakage amount for some hours in the night time.

5.2 Findings

The overall findings of the research work are classified under three heads and discussed separately:

1. Findings from an experiment
2. Findings from Observation / Survey
3. Findings from Interview

5.2.1 Findings from an experiment

Several opportunities can be unlocked by running a government based on data. This helps to discard the face-to-face delivery model and promulgate the policies in the interest of the public thereby creating much value to the people living around. For this reason, real-time data provided by the sensors in the flexible and scalable IoT-enabled system plays a significant role (Chatfield and Reddick, 2018). The primary concern of environment-friendly IoT is user satisfaction and is directly related to the quality of experience. It is, therefore, necessary to manage the network traffic in the core computing system of IoT because the demand of IoT services is increasing day by day (Huang et al., 2018).

The framework as shown in Figure 4.4 has been developed by choosing the sensor appropriate for the water supply sector. Kathmandu valley has been chosen as a spot to deploy the experiment. This framework is concentrated more on the technological infrastructure. This experiment has been used to realize the developed IoT framework.

The overall framework built is based on the literature review, opinions of experts and analysis of the contemporary trends. Sooner or later IoT will be recognized as a part of our lives. Extension of the services provided by this system in networking and communication from anywhere at any time is one of the major benefits derived from IoT applications.

The experiment was conducted for 360 days for 6 spots from 2019-07-15 to 2019-07-10 in Kathmandu valley but the data was generated for only 85 days from 2019-11-21 to 2020-02-13 for convenience. The status of consumption and leakage amount of water in these spots is shown in Figure 5.2. Problems were not reported by the house owners and they were delighted with having such a system installed at their house because IoT application prevented the overflow of water and also identified the leakage pertinent in all these 6 spots. The experiment tested in the IoT laboratory has been regarded as a baseline to IoT framework development shown in Figure 4.4. The result of the system and the expectation of the house owners were almost similar. However, there were some hassles regarding the mechanical part while installing the system in the water tanks especially, while mounting the sensor in the cover of the tank. The observation of the consumption and leakage amount of water in each of the 6 spots is depicted in Figure 5.2. In some spots, the leakage was insignificant whereas in some it was significant.

After observation of the data acquired, we can easily use it to observe the various trends among each of the household under experimentation. The average consumption of spot 1 over 90 days is found to be 17.19 liters, spot 2 is 33.275 liters, spot 3 is 40.94 liters, spot 4 is 37.25 liters, spot 5 is 54.75 liters and spot 6 is 33.95 liters. Similarly, the analysis can be expanded as mentioned in the framework for analysis of an entire city or province. Also, various methods can be implemented to forecast the consumption in near future. This forecast can help the water supply authority to predict the water resource need in the future and plan for it accordingly. Consumers can use the data to predict their own water usage. Nevertheless, after applying the billing formula, the total cost required for water can be predicted which can help in budgeting for consumers as well as the authority.

Furthermore, along with the consumption, leakage monitoring was also done. Aforementioned algorithm to detect leakage was used in the experimental spots. During the experiment, Spot 1 showed almost no leakage. During the time of Day 20 to Day 29, an average of 5.34 liters of water was reported as leakage by the system. This was not alerted to the household though the system because it was still under the threshold which was defined to be 10 liters per day although this threshold can vary. The threshold was set by speculative analysis only and it can be calculated by observing the various leakages after data from huge number of households is generated. In case of Spot 2 and Spot 3, there was almost no leakage.

At Spot 4 the average leakage is 13.25 liters. The water usage at nighttime was observed to go over the threshold level but there was no consistency so that it was also not reported as leakage. Such inconsistency is expected because there are times when people intentionally use water but the volume is generally very small and large volumes are also inconsistent over a period of time. In Spot 6, large volumes of usage are observed (greater than our threshold), but still due to inconsistency, it is also marked as human use.

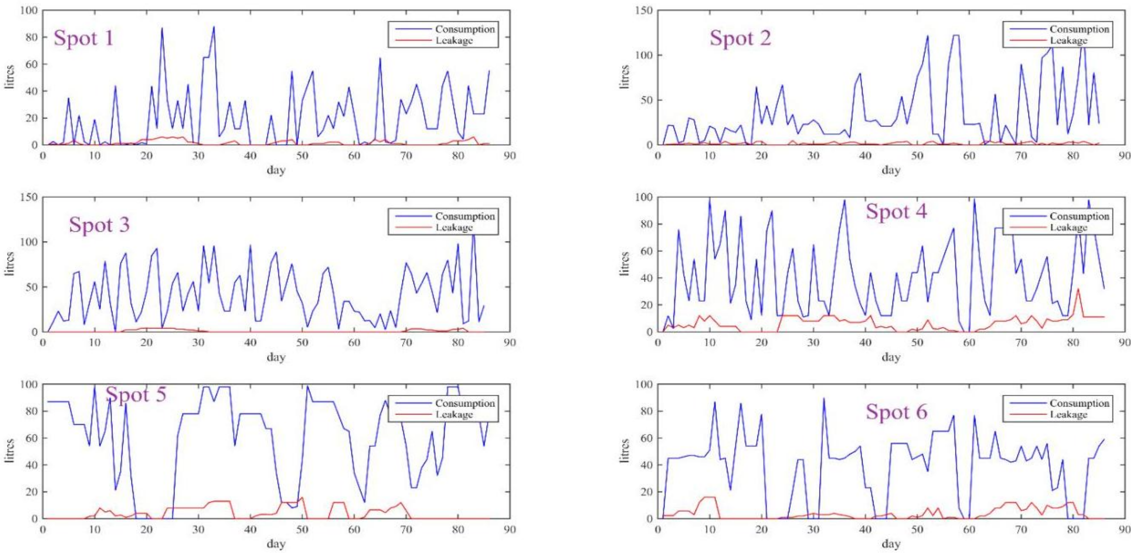


Figure 5.2: Consumption and leakage monitoring in all 6 spots

At Spot 5 though, during Day 22 to Day 36, an average of 10.38 liters of leakage was observed which was considered a leakage by this system and the issue was reported to the people there.

The framework so developed is scalable and the IoT structure does not change. Same device is installed in all the houses but the variable i.e. size of the tank varies according to the need of the household and it is addressed in the software section. Assigning the radius of the tank is one-time effort that has to be put on while installing the device/system. Each individual house is uniquely identified through an id given during the installation.

Table 5.1: Classification of water supplies all over Nepal based on province (NDWC, 2020)

Province 1		**Madesh Province**		**Bagamati Province**	
District	Number of Houses with Water Supply	District	Number of Houses with Water Supply	District	Number of Houses with Water Supply
Bhojpur	33078	Bara	94580	Bhaktapur	59748
Dhankuta	30492	Dhanusa	124129	Chitwan	145500
Illam	56051	Mahottari	96814	Dhading	75740
Jhapa	152991	Parsa	91857	Dolakha	45728
Khotang	38735	Rautahat	92719	Lalitpur	102386
Morang	185318	Saptari	106900	Kathmandu	416776
Okhaldhunga	30128	Sarlahi	128375	Kavre	84727
Pachthar	28015	Siraha	100618	Makwanpur	79676
Sankhuwasabha	31198	**Total 835991**		Nuwakot	60018
Solukhumbu	20928			Ramechhap	44947
Sunsari	128945			Rasuwa	9509
Taplejung	22798			Sindhuli	48127
Terathum	20989			Sindhupalchowk	62980
Udaypur	58365			**Total**	**1235861**
Total	**838030**				

The telephone survey has been done to find out the total number of water supplies provided by the department of water supply and sanitation. The Table 5.1 is presented by classifying the data based on the province and districts in the entire country.

The usability and the impact of the framework are wide since the number of water supplies all over the country (Nepal) is 4925831 (According to the survey conducted by Department of Water Supply and Sanitation, 2020), depicted in Table 5.1 and this number is in increasing rate. Nepal is still using traditional metering technique to know the consumed amount of water and the usage of this system will transform the country in managing the water supply sector.

Present day teamwork and initiatives taken throughout the world to encourage IoT in aspect of smart cities are shown by current open source IoT platforms for understanding smart city applications followed by many ideal case studies (Mehmood et al., 2017). It is anticipated that, by 2020 mega city corridors, integrated and networked smart cities will be developed. Likewise, it is presumed that, by 2025, 60 percent of people around the globe will reside in urban areas (Mir and Ravindran, 2017). In an IoT world, devices can be compiled as per their geographic location and evaluated through the application of analyzing systems (Talari et al., 2017). The IoT enables remote sensing and controlling of objects over current network resources. The Gartner estimates that by 2020, 260 million objects will be connected (Saleem et al., 2020). One of the bitter facts is sensor interfacing limits the number of connected devices and sensors to be connected in the IoT system(Khan et al., 2015). The deployment of application related to IoT could be tough and require large research and development efforts to tackle with the challenges, but it can provide substantial personal, proficient, and economic paybacks in the future (Khan et al., 2015).

Gandaki Province		**Lumbini Province**		**Karnali Province**		**Sudur-Paschim Province**	
District	Number of houses with water supply	District	Number of houses with water supply	District	Number of houses with water supply	District	Number of houses with water supply
Baglung	53873	Argha-Khachi	42170	Dai-lekh	40750	Accham	45952
Gorkha	61787	Banke	86577	Dolpa	7039	Baitadi	40308
Kaski	103183	Bardiya	77172	Humla	8938	Bajhang	26144
Manang	1273	Gulmi	68900	Jajar-kot	33293	Bajura	21897
Mustang	2798	Dang	87260	Jumla	17983	Dadel-dhura	26528
Myagdi	22983	Kapil-vastu	82693	Kali-kot	19224	Dar-chula	24298
Lamjung	35276	Nawal-parasi	58846	Muku	8337	Doti	36245
Nawal-pur	59410	Palpa	50368	Rukum	27438	Kailali	153615
Parbat	31432	Pyu-than	40559	Salyan	37648	Kanchan-pur	64489
Syangja	61629	Rolpa	40987	Surkhet	65970	**Total**	**439476**
Tanahu	69069	Rukum	10035	**Total**	**266621**		
Total	**502711**	Rupan-dehi	161574				
		Total	**807141**				

The tabulated data is shown in the map of Nepal in Figure 5.3.

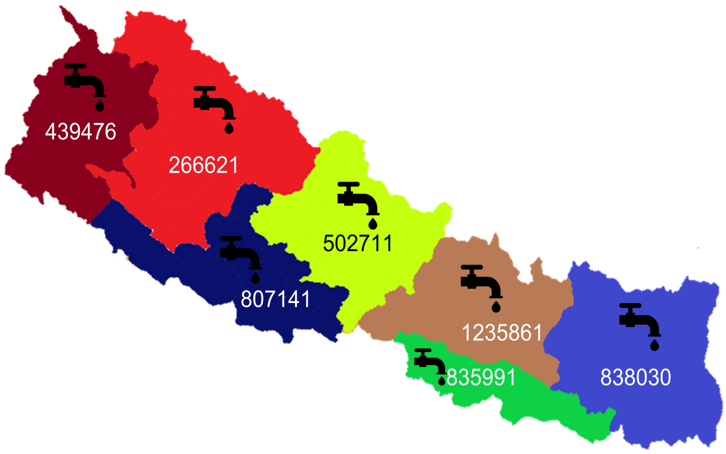


Figure 5.3: Number of water supplies in Nepal
(Source: composed by the author)

5.2.2 Findings from Observation / Survey

There are several parameters that needs to be viewed and analyzed to check the present infrastructural status of Nepal to implement IoT framework, these parameters depict the position of Nepal in global perspective. After visualizing the position, where and what efforts should be given and how the effort has to be put on can be known to gain several insights. These are very essential for improving and upgrading the existing system as well as developing new systems to facilitate the citizens. The observational survey was carried out from 2019-06-04 to 2021-06-03.

5.2.2.1 Global ICT Development Index (IDI) and Nepal

The key technique to identify the ICT development of any country in the world is IDI. IDI contains 11 different indicators that holds basis of ICT progress. The IDI Index of Nepal 1.28 in 2008 & 1.56 in 2010, 2.88 in 2017, thereby Nepal ranked as 140 out of 176 economies (Afghanistan: 159, Pakistan: 148; Bangladesh:147; Bhutan:121; India:134; Srilanka:117; Maldives:85) (Union, 2017).

5.2.2.2 Telecommunication and internet services

Nepal Telecommunications Authority (NTA) publishes Management Information System (MIS) report every month which gives the detail statistics about the Telecom industry and User Penetration. The statistics presented by NTA is expressed in in terms of % of Population in that year. The telecommunication and internet services are classified under different categories:

1. **Tele density and internet penetration**

   As shown in Table 5.2, there is increasing trend of the Tele density Percentage and Internet Penetration from 2015 to 2020 but the percentage is reduced in the year 2018 as NTA excluded Data/Internet Service through GPRS Service in Broadband subscription. From 2018 the internet penetration is increasing where as the tele-density is decreasing. This data gives message that people are inclined more using internet service more than using telephone services and this is a positive signal for the implementation of IoT systems.

Table 5.2: Tele-density and internet penetration (Nepal Telecom Authority, 2021)

Year	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
Tele-density	111.54	127.67	142.63	136.44	135.46	126.20
Internet Penetration	47.24	55.03	63.81	56.71	58.77	76.67

2. **Broad band services**

   The details about Fixed (wired), Fixed (wireless) and Mobile Broadband service can be observed from Table 5.3. The usage of broadband services seems to be increasing in a high rate. The percentage increase from 2018 to 2020 is 37.3627%. Again this is also a positive signal for IoT implementation.

Table 5.3: Summary of broadband services (Nepal Telecom Authority, 2021)

Broadband Categories	**Service type**	**2016**	**2017**	**2018**	**2020**
Fixed (Wired)	ADSL	183315	195906	1017446	924614
	Modem Cable/ Optical Fiber	205853	290212	2239719	4571637
	Internet Lease Line			716	1094
Fixed (Wireless)	Wi-Fi		51251	273036	132574
	WiMAX	16186	17075	87811	90319
Mobile	3G			10467529	11551663
	4G			2389381	5497332
	CDMA 1X, EVDO	199599	199771	199776	136573
Total		**604953**	**754215**	**16675414**	**22905806**

3. **Mobile and Fixed telephone penetration**

   Figure 5.4 shows that the rate of mobile phone penetration is 98% and Fixed Public Switched Telephone Network (PSTN) is 2%. These people are enticed to use mobile phones more than PSTN.

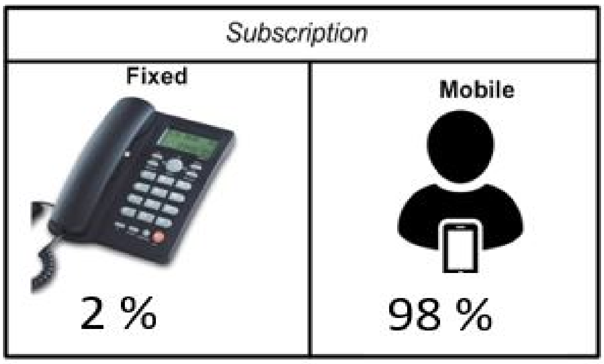


Figure 5.4: Mobile and Fixed telephone penetration in 2018 (Nepal Telecom Authority, 2021)

4. **Internet statistics 2019**

   Use of internet service in Nepal is tremendously increasing from 2008. The users of internet has reached to 89% of total population in 2020. The statistics of broadband internet service according to NTA is shown in Figure 5.5.

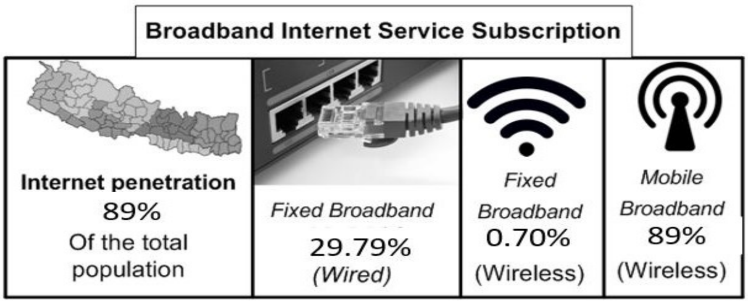


Figure 5.5: Broadband internet service 2019 (Nepal, 2020)

5. **Internet Service Providers in Nepal**

   As per the MIS report of NTA (2019), Worldlink Communications Pvt. Ltd, Nepal Doorsanchar Company Limited, Subisu Cablenet Pvt. Ltd., Vianet Communications Pvt. Ltd. and Classic Tech Pvt. Ltd. are top 5 operators with highest number of subscribers. Table 5.4 shows the current Operators with numbers of subscribers associated with them. NTA has provided the licenses for the below mentioned operators for different kinds of services.

6. **3G and 4G penetration in Nepal**

   There is increasing interest of private sectors to invest in telecommunication industry in Nepal due to less competition and increasing demand for the services like data. Mobile operators have concentrated to increase 4G coverage from 2017. These operators believe that 4G services will be in priority up to 2023.(Nepal, 2020).

Table 5.4: Company wise internet subscribers as of July, 2021 (Nepal Telecom Authority, 2021)

S.N	**Service Provider**	**Total (Wireless + Cable + Fiber)**
1	Worldlink Communications Pvt. Ltd., Jawalakhel, Lalitpur	394010
2	Nepal Doorsanchar Company Limited	249596
3	Subisu Cablenet Pvt. Ltd. Baluwatar, Kathmandu	146340
4	Vianet Communications Pvt. Ltd., Jawalakhel, Lalitpur	113931
5	Classic Tech Pvt. Ltd., Baneshwor, Kathamandu	110787
6	TechMinds Network Pvt. Ltd. , Narayangarh, Chitwan	42908
7	Broadlink Network & Communication Pvt. Ltd. , Kathmandu	32853
8	Web Surfer Nepal Communication. System Pvt. Ltd., Kathmandu	18664
9	Arrownet Pvt. Ltd. , Tripureshwor, Kathmandu	11206
10	Himalayan Online Services (Pvt) Ltd., Kathmandu 6,018	6052
11	Sky Cable Tv Pvt. Ltd.	5604
12	Net Max Technologies Pvt. Ltd., Anamnagar, Kathmandu	5523
13	Eastlink Technology Pvt. Ltd., Tripureshwor, Kathamandu	7840
14	Pokhara Internet Pvt. Ltd., Pokhara, Kaski	3002
15	Barahi Internet Techanologies Pvt. Ltd., Srijana Chowk -8,	4082
16	Cherry World Communications Pvt. Ltd.	1522
17	Acme Technical Institute	1475
18	Mercantile Communication Pvt. Ltd., Durbarmarg, Kathmandu	2078
19	IZone Pvt. Ltd.	1312
20	Ibss Nepal Pvt. Ltd., Sinamangal, Kathmandu	1109
21	First Link	5204
22	Fiber Online Pvt. Ltd., Jawalakhel, Lalitpur	474
23	Japan Nepal Information Communication Technology, Kalikasthan	330
24	Metrolink Business Group Pvt. Ltd.	306
25	Galkot Link Pvt. Ltd.	300
26	Gandaki Communication	287
27	Simrik Internet Pvt. Ltd.	176
28	Sustainable Network Pvt. Ltd. Pulchowk, Lalitpur	192
29	Earthlink Communication Enterprise Pvt. Ltd.	136
30	Big Marshyangdi Net Pvt. Ltd.	115
31	Meta Link Pvt. Ltd.	226
32	Hawk Net Pvt. Ltd.	103
33	Broaband Solutions Pvt. Ltd.	98
34	Nepal Net Sanchar, Biratnagar	83
35	Vns Technology Pvt Ltd Dhanusha	75
36	Unified Communication Pvt. Ltd.	42
37	Shikhar Net Pvt. Ltd. ,Dhanagadhi, Kailali	30
38	Surkhet net cable Pvt. Ltd.	600
39	Lifenet Pvt. Ltd.	178
40	WebNetworks Pvt. Ltd.	885
41	Clean Network Pvt. Ltd.	21
Total		**1169761**

5.2.3 Major Software Companies in Nepal

There is no proper database to identify the software companies with proper category and service they provide. From the survey, the list of software companies as shown in Table 5.5 have been found working in different categories and providing services in the software industry.

Table 5.5: Major software companies in Nepal

Company Name	Estd.	Category	Service
Agile IT Solutions	2013	Web Development	Web hosting Web design
Braindigit IT Solution	2008	Web Development	Business Application Development, Enterprise Content Management, Mobile App Development and Collaborative Ecommerce Solution.
Deerwalk	2009	Healthcare Data Analytics, Big Data	Performing Health Analytics solutions built on a foundation of data integrity
F1soft	2004	Finance	Services to more than 90% of the banks and financial institutions in the country
GrowByData	2014	Data Analytics	Help online retailers sell and increase profits through Amazon and Google
Javra	2006	Big Data Business Intelligence	Modern Web Apps, Mobile Apps, Big Data/Business Intelligence and E-commerce
Leapfrog Inc.	2010	Healthcare	Healthcare, Edtech Consumer, and all things on data.
Verisk Nepal	2009	Insurance Energy Finance	Data analytic insights to customers in insurance, energy and specialized markets, and financial services
Yomari	1997	Business Intelligence Data Analytics	Data warehousing, business intelligence, and analytics solutions
e-Rastra	2020	Enterprise Application And IoT	Services regarding EEA (Educational Enterprise Application) and IoT Solutions in national level

5.2.4 Data Centers and its services in Nepal

Leading data centers and Internet Services Providers (ISPs) are from private sectors in Nepal. Surprisingly it is seen that they lack maintenance and configuration management like in most of other countries. According to the survey carried out in 2019, it is found that most of Nepal's Data Centers provide collocation service or just network support services or managed service as shown in Table 5.6.

Table 5.6: Major Data Centers in Nepal (Nepal Telecom Authority, 2020)

SN	Name	DR/DC location	Service
1	Government Integrated Data Center (GIDC)	DC in Singha Durbar, kathmandu and DR at Hetauda under construction	services to government agencies Web Hosting Co-Location Network Management email servers Virtualization and Cloud Service and other web applications
2	Access World	DC in Pulchowk but DR not in Nepal	Cloud VPS Web Hosting Enterprise Secure Email Endpoint Security Domain SSL Certificate Co-Location Veeam Backup and Replication Services C-Panel
3	Cloud Himalaya	DC in Thapathali, Kathmandu and DR in Itahari	Co- location services, disaster recovery Managed Services Cloud Services
4	Data Hub	DC in Thapathali, Kathmandu and DR in Butwal	Co- location services, data and network security, disaster recovery Managed Services Cloud services
5	OHM Data Center	Located in Bhairawa primary as DR site	Co-Location Cloud Services Tape Storage Facilities Disaster Recovery Services Managed IT Infrastructure & Database Services

The implementation of smart city is getting special attention for both academicians and policy makers. Beside this, several ongoing research approaches and industry efforts are aiming at developing standards and best practices to define the concept of IoT platform for Smart Cities. Some recent research has been proposing the concept of subgroups for the planning and organization of cities without losing this vision (Jordão et al., 2018)

Abundant research and studies have been carried out to adopt IoT in technologies. The studies have depicted that there are many barriers and challenges to enable IoT in recent technologies. Special consideration from political, community and governance level has to be given to incorporate IoT in the several sectors.(Kumar et al., 2019)(Dachyar et al., 2019)

5.3 Findings from an interview

Though the concept of developing smart city in Nepal is burgeoning, the implementation phase and action plan is getting tedious. Inadequate research in the area and lack of essential infrastructure does not still allow Nepal to develop smart city. Many government officials and municipalities directors have a different understanding of what the smart city means. In this research, an interview was carried out with the government officials, municipality Mayors, Directors, and some IT and engineering professions to know about the underlying infrastructure and feasibility of smart city. Altogether 23 interviews as a part of qualitative research were conducted to find out the answer to know where the problem is to establishing efficient smart city. The result of the interview depicted that, lack of political initiation and commitment is the major problem and the second problem has been seen as low computer literacy, similarly lack of Public Private Partnership (PPPs) in establishing e-Government system, reluctancy in technological usage and advancement are the major hindrances to developing smart city. Knowledge regarding Internet of Things (IoT), low awareness of about e-Government system is found to be other barriers to develop the smart city. The interview was conducted from 2019-02-16 to 2020-02-06

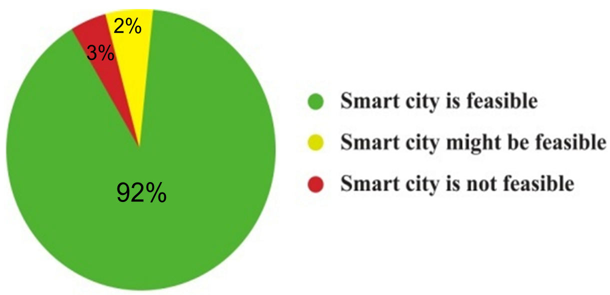


Figure 5.6: Feasibility of smart city in Nepal

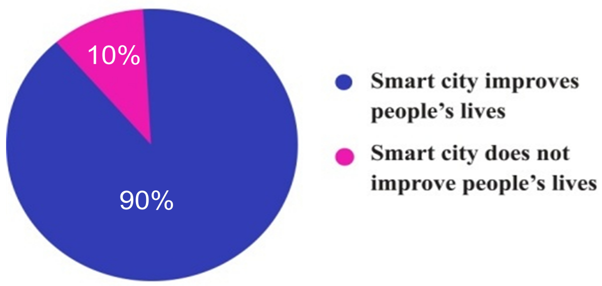


Figure 5.7: Smart city and peoples lives

According to the data obtained from an interview 92% of the respondents believe that smart city is feasible in Nepal, 3% believe that it is not feasible and the rest 5 % are not sure about implementing smart city in Nepal as depicted by Figure 5.6. Similarly, 90% of the respondents believe that development of smart city improves people's lives and 10% don't believe it, as depicted by Figure 5.7.

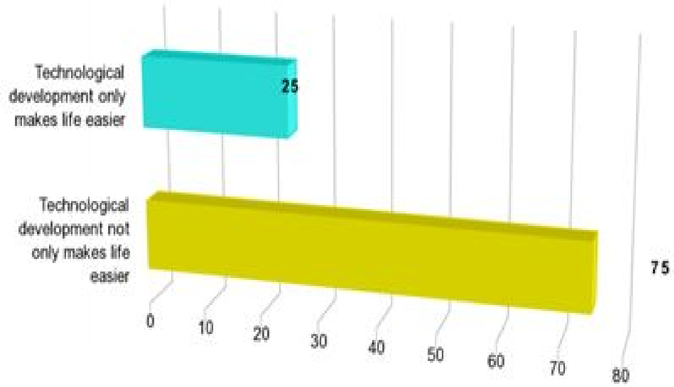


Figure 5.8: Technology and ease of life

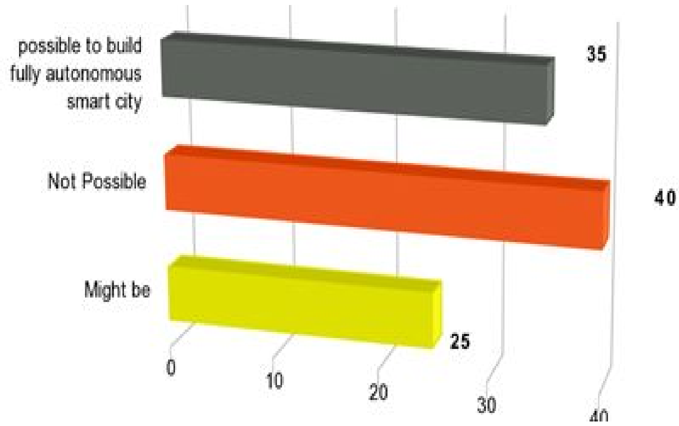


Figure 5.9: Possibility of building fully autonomous smart city

Figure 5.8 shows that, many of the respondents (75%) replied that technological development not only make life easier but also ease people in different ways. Figure 5.9 depicts that possibility of building fully autonomous smart city is obtained as 35% and the neutral respondents are obtained as 25%. Similarly, the interview also revealed that the available technological infrastructure is inadequate to build smart cities and it is depicted by Figure 5.10. As shown in Figure 5.11, 45% respondents believe that human civilization changes due to usage of IoT, whereas, 15% of them don't think usage of IoT will change human civilization and 40% of respondents replied that they don't know what will happen after using IoT.

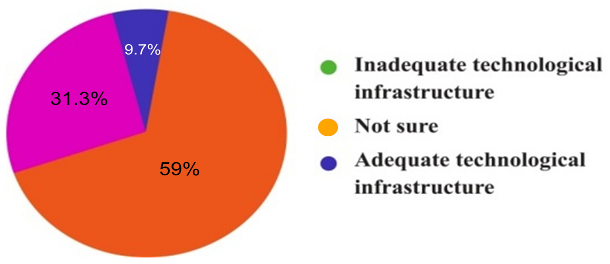


Figure 5.10: Availability of technological infrastructure

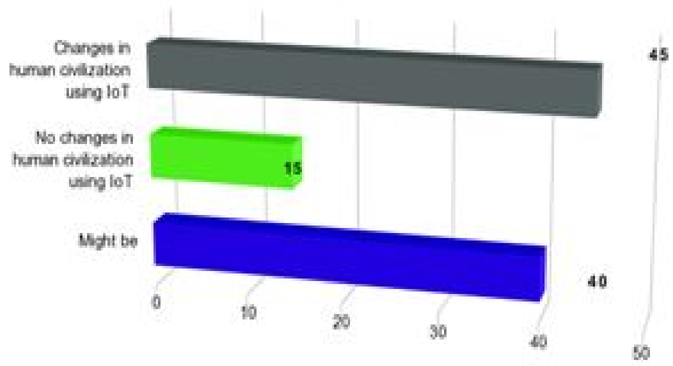


Figure 5.11: Human civilization and IoT

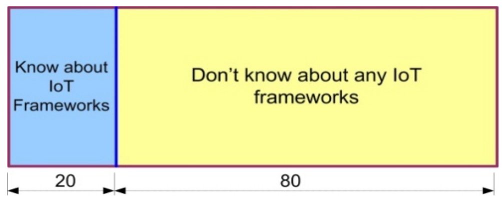


Figure 5.12: Aware of any IoT framework

As depicted in Figure 5.12 and 5.13, 80 % of the interviewees don't have idea about any IoT frameworks and they think that the security of data transfer in deployment of IoT is critical.

Figure 5.13: Security of data in IoT framework

50% of the respondents assume usage of IoT will have only positive impact on infrastructure and smart city regions, whereas 30% believe that it will have both positive and negative impact and 20% believe that usage of IoT will have only negative impact on infrastructure and smart city regions as exhibited in Figure 5.14.

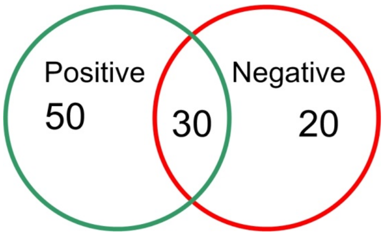


Figure 5.14: Impact of IoT

Figure 5.15 shows that technology changes people in two different ways; one is changes in life style and the other is transparency. This result from the interview revealed that 85% respondents believe that technology will bring changes in life style and 7% believe that technology changes people because the process of doing work becomes transparent. The dots in Figure 5.15 shows the number of respondents. The survey and interview also provided the data that, internet enabled service, usage of IoT and smart phone is predominant in the field of smart sustainable cities.

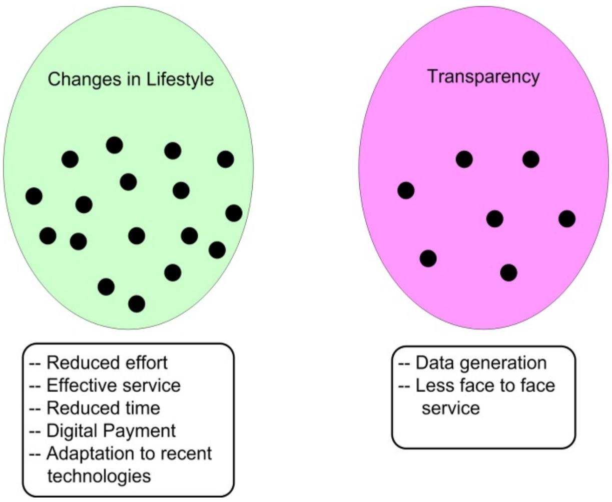


Figure 5.15: Changes brought in people by technologies

Time saving, no queue; ease service providers, maximum usage of IT, low cost services and citizen friendly services are found to be the sustainability factors in IoT for smart city. Similarly the interview conducted with several officials came out with the fact that, legal policies, punitive measures and cryptographic measures are the possible permanent solutions to solve the security threats on IoT. Political commitment, innovative project initiation and raising public awareness are the major role of the government in the smart cities. The available infrastructure to implement smart cities is depicted in the Figure 5.16. Some exceptional answers, digital payment, smart city project initiation and budget allocation were also obtained as available infrastructure to implementing smart cities.

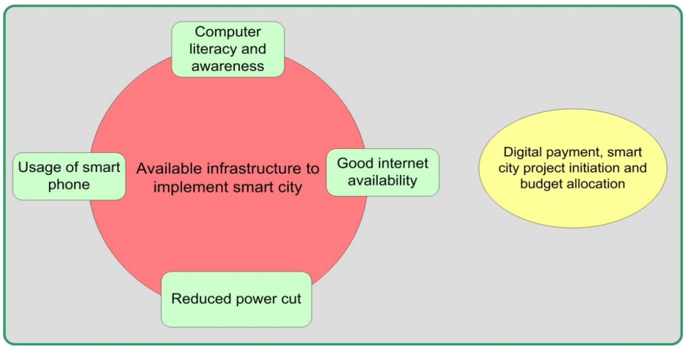


Figure 5.16: Prevalent infrastructure to implement smart city

Changes in working procedure, good governance, transparency, efficient service delivery and quick adaptation to technology are the evidence to show how the human civilization changes due to usage of IoT. Sound infrastructure, maximum usage of IT, efficient services and enhanced quality of life are discovered as the major characteristics of sustainable future smart city. Similarly, online services, mobile applications and IoT devices are the technologies used in the development of computerized smart systems as per the voice of interviewees.

The data obtained from an interview and survey was very significant to dig out the infrastructural status to develop smart city in Nepal. It is believed that smart city is feasible and can be built in Nepal, but the existing infrastructure is not adequate to develop the smart city. The political commitment, innovative project initiation and support, and raising awareness to actively participate in developing smart cities are found out to be the major role of government to build smart cities. Reduced effort in doing things, effective service, digital payment services, and data generation are the major attributes how the usage of IoT will bring changes in the life of people living around. Security of data transfer is considered very critical while penetrating the usage of IoT applications. However, legal policies, punitive measures and cryptographic usage can solve the security threats on IoT. Physical queue is not mandatory after using online services in IoT applications and internet based services helps the municipality to be more creative and deploy citizen friendly services. Some of the available infrastructures are found out to be increasing usage of smart phones, good internet availability, and increasing awareness and computer literacy. Penetration of digital payment is also a good infrastructure to develop smart city in Nepal. It is also found that human civilization changes due to usage of IoT by the changes in working style, good governance, transparency and efficient service delivery. Citizen can participate in smart city just by using the IT enabled services and adhering to the legal procedures associated with the online systems. In a nutshell, the efficient participation of the citizens while using the services, robust service delivery from the service providers, and creating amicable environment by the government to establishing smart cities are the main ingredients to add and update the required infrastructure to develop smart cities.

5.3.1 Cross-tabular analysis

The answers provided by the respondents were analyzed and the answer of one question was connected to the answer of other question, therefore the cross tabular analysis of obtained data has been found to be relevant to dig out other facts related to infrastructure analysis for smart city in Nepal. The following are the relation derived from answers provided by the respondents.

1. Those respondents who think the concept of smart city is feasible in Nepal also think that smart cities improve people's lives and also believe that technological development does not only make life easier but also entice people to use web based system.

2. Though respondents have positive attitude towards feasibility of building smart cities in Nepal, most of them don't think that it is possible to build fully autonomous smart city.

3. Those respondents who don't know about any IoT frameworks also think that security of data transfer in IoT is critical. This gives us the insight that people are highly sensitive towards the security issues of data transfer, though they don't have knowledge regarding recent technologies.

4. When the possibility of building fully autonomous smart city decreases, then the availability of technological infrastructure also decreases.

   This information envisage that it is possible to build smart city in Nepal but there is inadequate technological infrastructure.

5. Respondents who knew about available IoT frameworks believed that the security threats on IoT can be solved and possible permanent solutions as per the respondents were:

   a. Adoption of legal policies and procedures

   b. Punitive measures for security breach

   c. Cryptographic measures to be applied in the system

CHAPTER 6

DISCUSSION

The development of the IoT framework requires an experiment, review of literature, survey, and analysis. After performing all these activities, verification and validation of the developed framework using scientific methods needs to be done. In this study the type of experiment and survey has been summarized and finally using rigorous analysis, a framework has been recommended. The water supply management sector has been considered to narrow down the research work. The infrastructure analysis has been carried out followed by the observation and interview taken with key peoples of Nepal government, the outcome of the interview are listed below:

1. Sustainability factors in IoT for smart city are; Time saving, no queue, ease service providers, maximum usage of IT and nevertheless, low cost services and citizen friendly services.

2. Similarly, the interview conducted with several officials came out with the fact that, legal policies, punitive measures and cryptographic measures are the possible permanent solutions to solve the security threats on IoT.

3. Human civilization also changes if the concept of IoT is implemented in nation. Changes can occur in working style, good governance, transparency, efficient service delivery and quick technology adaptation. Political commitment, innovative project initiation and raising awareness are the major role of the government in the smart cities.

4. Technology that dominates the field of smart cities is the usage of Smart Phones and mobile applications

6.1 Verification, Validation and Reliability

The verification part answers the question; did we build the right framework? Whereas the validation part answers the question; did we build the framework right? For both of these, the major tool to use has been reviewed.

Review and discussion session was established with the experts in the field and update or modification was done in the developed framework. The system has been installed for about a year in the houses by taking the authority of the house owners.

Implementation of IoT application in water supply sector in Nepal is in the budding phase. The coding in raspberry pi is done using python language and the details of the

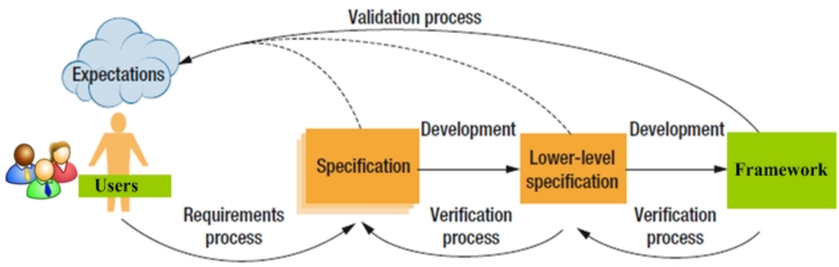


Figure 6.1: Verification and validation process

hardware used in the experiment are shown in Table 3.1. The complexity contained in programming and system development has not been stressed in this research though it was there. The major focus is on the development of IoT framework. This research work has been planned to be used by the government of Nepal and the evidence is shown in Figure 6.2.

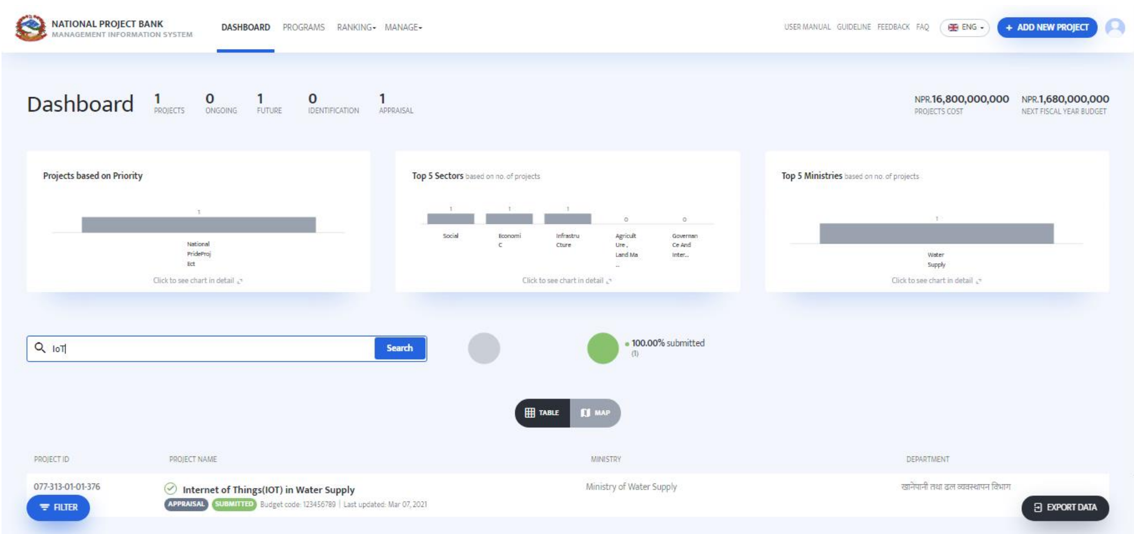


Figure 6.2: Inclusion of research work in National Project Bank, GoN
(Source: National Project Bank Management Information Sytem (NPBMIS))

The experiment using setup as shown in Figure 5.1 was conducted for 360 days for 6 spots in Kathmandu valley but the data was generated for only 85 days. The status of consumption and leakage amount of water in these spots is shown in Figure 5.2. Problems were not reported by the house owners, they were delighted with having such a system installed at their house because this IoT application prevented the overflow of water and identified the leakage pertinent in all these 6 spots. The experiment tested in the IoT laboratory has been regarded as a baseline to IoT framework development shown in Figure 4.4. The result of the system and the expectation of the house owners were almost similar.

For the reliability of the developed framework, the SHARPE tool was used. The features of SHARPE has been studied and in crux, the details of the tool is displayed in Figure 6.3.

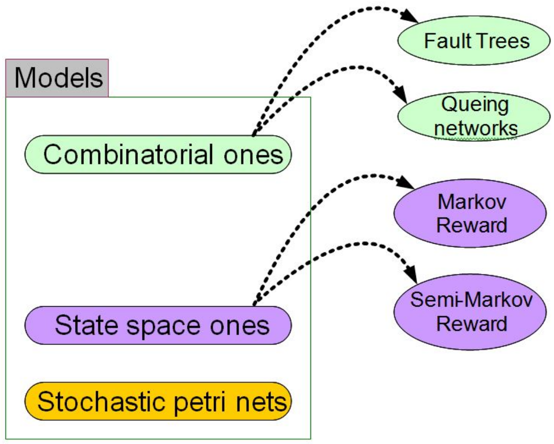


Figure 6.3: The models covered by SHARPE

By analyzing several tools to check the reliability of the developed framework, it has been found that SHARPE best suits to this research. Steady state, transient and interval measures can be computed SHARPE. For most of the model types, SHARPE provides more than one analysis from where user can choose those that he/she needs. In a nutshell SHARPE is a tool used for modeling real systems. For the developed IoT framework combinatorial ones has been found to be useful.

MIL-HDBK-217, ARIES'76 and ARIES'82 are some tools used for testing the reliability of the system. Due to the convenience, availability upon request and its usage by number of researchers, SHARPE has been taken as a reference in this study.

Uncertainty quantification of the sensors was conducted. The systematic uncertainty (S_U) is the sum of error data generated by the sensor (S_E) divided by the number of repeatability test and the random uncertainty (R_U) is the sum of error data generated while measurement (M_E) is taken in random manner. The total uncertainty (T_U) is the square root of sum of square of measurement error and square of error data generated by the sensor. This is depicted in equation (11), (12) and (13). A repeatability test, i=1 to 50 were conducted before deploying the IoT system in the field. The systematic uncertainty (S_U) has been obtained as S_U=±0.18% and the random uncertainty (R_U) has been obtained as ±0.16%. The total uncertainty has been obtained as ±0.24%, which is computed using the equation:

$$Systematic\ \ Uncertainty\ \ (S_U) = \frac{1}{50}\sum_{i=1}^{50} S_E \ldots\ldots\ldots\ldots\ldots\ldots(11)$$

$$Random\ \ Uncertainty\ \ (R_U) = \frac{1}{50}\sum_{i=1}^{50} M_E ....(12)$$

$$Total\ \ Uncertainty\ \ (T_U) = \sqrt{S_U^2 + R_U^2} ....(13)$$

The random uncertainty is less than systematic uncertainty and total uncertainty. This proves that the system is reliable. The major problem and the reliability of the system hinders if the sensors do no perform well. The condition of the total probability of failure (Fp) = 0.24% reflects the reliability of the system (Rs) = 99.96%. The benchmark for the uncertainty level for both systematic and random uncertainty is $\leq \pm 0.5\%$. After the sensors are used for a year, again the reliability needs to be measured which should not be less than 99.95%. (Athans et al., 1977)

Madina, 2018 in his study entitled, "A Reliable Communication Framework and Its Use in Internet of Things (IoT)" obtained the reliability of 99.70%. Similarly, Shenshen Tang and Yi Xie, 2021 in their study entitled, "Availability Modeling and Performance Improving of a Healthcare Internet of Things (IoT) System" obtained the reliability of 98.03%. The reliablity of our system also obtained similar results.

The experimental section of the framework has been validated experimentally. However, the uncertainty associated with the sensors have been calculated and compared with the uncertainty obtained by similar studies.

The paper entitled "Trends and Applications of Machine Learning in Water Supply Networks Management", provides the concept of how machine learning algorithms has been applied to identify the leakage of the water supply pipes (Liakos et al., 2018). According to the study real case data was taken from thirteen different studies around the globe (Liakos et al., 2018). The different machine learning model used in different studies were discussed in this study and the basic concept used is depicted in Figure 6.4.

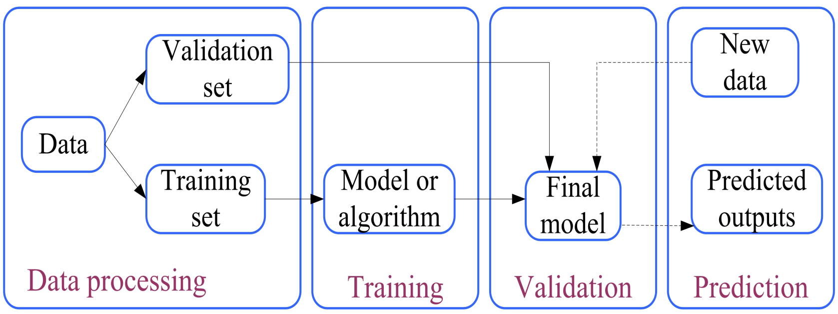


Figure 6.4: Implementation stages of a supervised machine learning system (Liakos et al., 2018)

The result of the study suggested that trivial numbers of water pipes fail, so that, sampling method to train classifier was recommended (Liakos et al., 2018). But if regression system has been used, sampling method is not essential. The result also found that transforming and scaling the variables is directly proportional to the performance of the model being employed (Liakos et al., 2018).

Similarly, another paper entitled "Machine Learning in Agriculture" has reviewed about how crop yield can be increased using machine learning algorithms. The study has enlisted that; support vector machine (SVM) has been used in coffee and green citrus production with an accuracy of 82.54–87.83% and 80.4% respectively. Similarly, Bayesian model (BM) has been used in cherry production with an accuracy of 89.6% (Alicia Robles Velasco, 2021). This paper considers the framework of machine learning as shown in Figure 6.5.

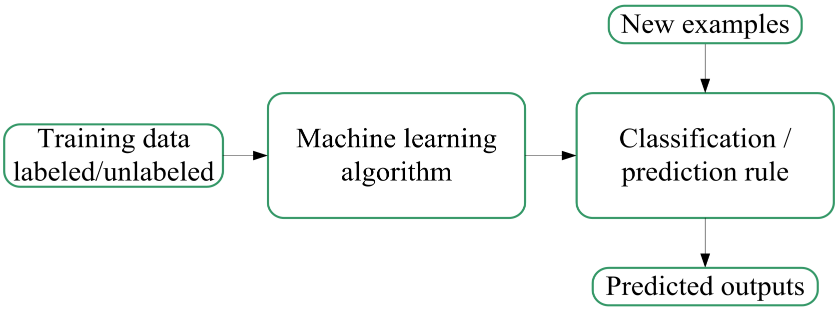


Figure 6.5: A typical machine learning approach (Alicia Robles Velasco, 2021)

The concept of machine learning has been incorporated in IoT framework development. As per the concepts shown in Figure 6.4 and Figure 6.5, the portion as shown in Figure 6.6 has been integrated in the IoT framework.

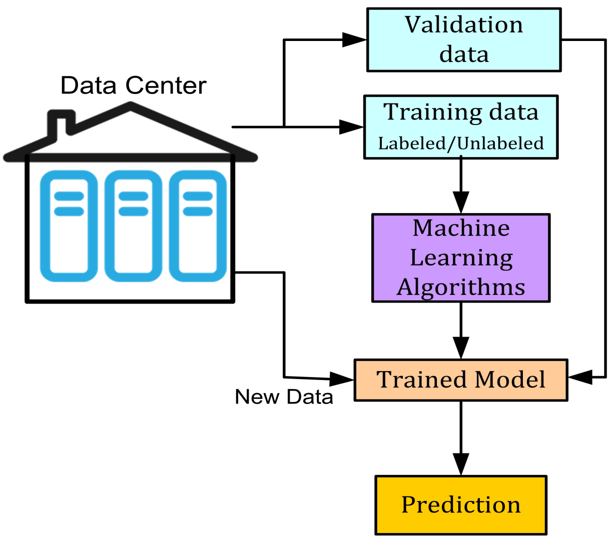


Figure 6.6: Machine learning segment in developed IoT framework

As mentioned in the Technology Acceptance Model (TAM), the perceived usefulness, social factors and ease of use are the factors that develops attitude towards using the technology. The findings from the interview in this study shows that, time saving, reduced waste and maximum usage of internet are entities that contributes to the perceived usefulness. Similarly, data security and support services are the entities that contributes to the social factors. The factors under perceived usefulness, ease of use and social factors are depicted in Figure 6.7.

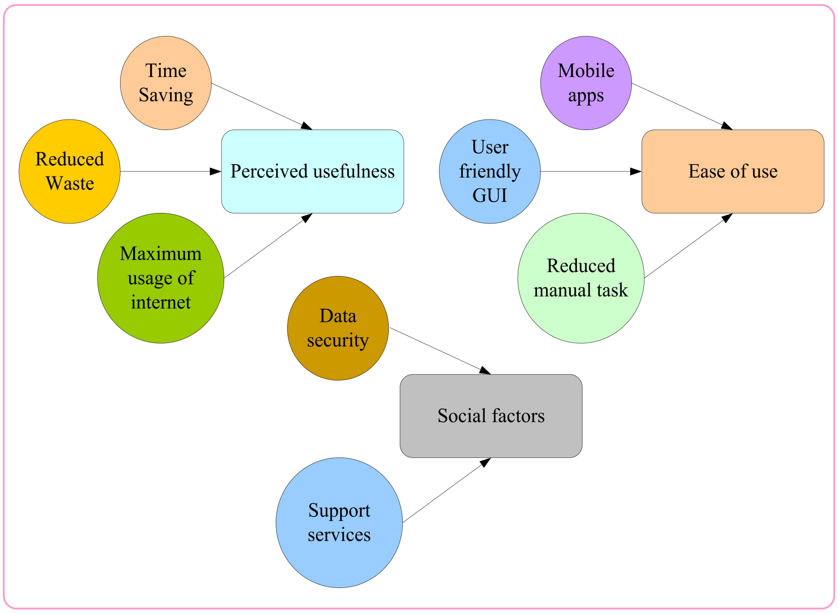


Figure 6.7: factors influencing perceived usefulness, ease of use and social factors

User friendly Graphical User Interface (GUI), mobile applications and reduced manual work contributes to the ease of use in TAM. The attitude of customers is the perception of using IoT system, which in turn behavioral intention in using IoT system.

CHAPTER 7
CONCLUSIONS

7.1 Conclusion

This study has developed one generic IoT framework that can be directly put into practice. To realize the experimental section of the framework, water supply sector has been chosen. This sector has been selected because water is a fundamental need and transformation of a society can be started from here. An efficient management of water supply sector can be done by obtaining the consumed and leakage amount of water. The experiment in this system has developed an IoT system which contains sensors and microcontrollers that is embedded in a device. This device is expected to be mounted in the water reservoir of individual house. This framework was deployed in six different spots and no problems were reported by the users. The consumption level (CL) and leakage reporting (LR) data is continuously transmitted to data center by taking an average of 20 data at a time to reduce the effect of erroneous data. From the data of CL, bill amount (BA) can be calculated. The management of garbage, pollution, road traffic and house hold services can be done by applying the IoT framework in respective sectors. Almost all of the manual tasks gets automated by adopting the developed framework. In a nutshell, this study provides an authentic and tested IoT framework that can be applied in many sectors.

There is direct connection between IoT and smart city. Though the concept of developing smart city in Nepal is burgeoning, the implementation phase and action plan is getting tedious. Inadequate research in the area and lack of essential infrastructure does not still allow Nepal to develop smart city. Many government officials and municipalities directors have a different understanding of what the smart city means. In this research an interview was carried out with the government officials, municipalities Mayors, Directors, and some IT and engineering professionals to know about the underlying infrastructure and feasibility of smart city. Altogether 23 interviews as a part of qualitative research were conducted to find out the answer to know where the problem is to establishing efficient smart city. The result of the interview depicted that lack of political initiation and commitment is the major problem; the second problem has been seen as low computer literacy; similarly lack of Public Private Partnership (PPPs) in establishing e-Government system and reluctance in technological usage and advancement are the major hindrances to the development of smart city. Knowledge regarding Internet of Things (IoT), low awareness of e-Government system is found to be other barriers to develop the smart city.

IoT can be a major tool to make the city smart but the way to use it and gain the trust of citizens is major things of concern so a suitable framework to use it is vital. Embedded system interfacing several sensors within it helps collecting and analyzing data. This data can be used by the cities in improving communal services, infrastructures and so on. literacy rate, users acceptance, security threats, existing infrastructure, technical expertise, maintainability, ability to upgrade the system are the entities that enables to make the city smart. Expert opinion, cluster testing, verification and validation of the developed IoT framework are a matter of concern. This research is basically focused on developing the Model of IoT framework which suits the infrastructure of Nepal for smart city.

7.2 Novelty of the developed framework

Nevertheless, the framework as an output of this research work doesn't focus only on the model but an entire ecosystem from generation of data to its effective application. As such, following are the core features of this framework and the experimentation which can be regarded as the novelty of the developed framework:

1. The framework developed is generic and can be used in several sectors like water supply, electricity supply, agriculture, irrigation and so on.
2. The developed framework focuses both on data generation and its application. The experimental setup defines a methodology of how the various hardware and software technologies can be layered such that each aspect of the system can be handled uniquely.
3. This framework also contributes on forecasting or prediction and knowledge discovery regarding the system by using the real data.

7.3 Contribution of the research work

The contribution of the research work is classified under the following heads:

7.3.1 Research contribution

Recently many researchers are enticed to carry out a research in the field of IoT. This is the first research done in IoT framework development in Nepal. Therefore, new researcher can carry out the research starting from the end point of this study. The other research contribution of this research is listed below:

1. This academic work can act as a stepping stone to new researcher to conduct new study regarding IoT.

2. The research paper published in International Journals is available online, so the researcher around the globe can have access to this piece of research work to expand their knowledge and their level of thinking.

3. The three research papers as an output of the study has contributed something to the world of literature in computer engineering field.

4. The mathematical model developed from the experimental section of the research is limited to water supply sector. This model can give insight to the researcher working for IoT in other sectors like electricity, energy, Agriculture, irrigation and other sectors as well.

7.3.2 Practical contribution

The society these days is moving towards reducing human computer interaction to as more as possible and this is what the field of IoT aims for. The practical contribution of this study is listed below:

1. The outcome of this research is generalized IoT framework that can be used in many fields, and this eases in reducing the effort to search for any relevant IoT framework.

2. The Government of Nepal has planned to use the developed IoT framework in water supply management sector. Sooner or later this study helps citizens to save their time and effort by automating the manual task.

7.3.3 Organizational contribution

Many organizations are seeking to inject recent technologies in their respective businesses. The knowledge created by this study helps the organization of national and international level in the following ways:

1. This research opens a new gate for doing different business, like establishment of data centers for real time data management, establishment of call centers to help citizen to provide prompt service, device manufacturing for injecting new technologies like IoT Box and so on.

2. The existing organizations can understand and use the IoT framework developed in this study as per their need and strengthen their organization.

7.3.4 Limitations in this research work

Though the developed framework is novel, it has limitations such as:

1. The water supply sector has only been considered to realize the developed framework.
2. The framework focuses on storage and processing of huge amount of data and the experiment in this research has not employed self-scaling servers.
3. Only six spots were chosen to deploy the experimental prototype and data collection.
4. The setup at each spot is done using hardware, and the system has not yet shifted to cloud computing.

7.3.5 Future Steps of the research work

The research work does not end here as the future steps of the research can be carried out considering the following tasks:

1. The above listed limitations can be mitigated to carry on the future research in the same area. The methodology to identify the quality of water can be used in the future research works.
2. Effective protocol can be defined for ensuring information security.
3. Data analysis and modeling can be done after collecting significant amount of data.
4. The framework doesn't focus on standardized software protocols and methodology as IoT is still in early stage and its scope is still not limited. So, the framework can be enhanced to have standard software protocols based on the application.

7.4 Recommendation

This research is not a panacea but can be a solution to many problems implementing smart cities. Automating the manual task in the sector that includes fundamental needs is the first step to make the city smart. This research has narrowed down the task limiting to water supply sector. The recommendation to a university and related organization are:

1. Since this study has considered water supply sector, interested universities are recommended to extend this research to other sectors as well.
2. Organizations planning to introduce IoT in business are recommended to use the outcomes of this research because the prototype has been tested and used for about two years.

3. The ministries and Government of Nepal are recommended to include IoT as one of the initiatives in Digital Nepal Framework because it contributes more in developing smart cities.

4. Government of Nepal should develop policies and recommendation framework on IoT.

In a nutshell, this research is focused more on water supply sector and it can be extended to other sectors as well. Future researchers can generalize the mathematical models developed in this research to their interest of research sector in the field of IoT and also can enhance the framework developed in this study.

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APPENDIX

Questionnaire for Interview taken with officials of Nepal Government involved in establishing smart city

Q1. Do you think the concept of smart city will be feasible in Nepal?

Q2. Does the development of smart cities improve people's lives?

Q3. How does technology change people? Does technological development only make life easier for people?

Q4. Is it possible to build a fully autonomous smart city?

Q5. What technologies dominate in the field of smart sustainable development cities?

Q6. What are the sustainability factors in IoT for smart city?

Q7. Can we solve security threats on IoT? If YES, then what are the possible permanent solutions?

Q8. Is the current technological infrastructural status adequate to develop smart city?

Q9. What should be the role of government in smart city?

Q10. Can you say me about the available infrastructure to implement smart city?

Q11. Do you think human civilization changes in a few decades due to usage of IoT in several sectors? How?

Q12. Do you know about any Framework for the IoT based Smart City Applications?

Q13.What are the characteristics of a sustainable future smart city?

Q14. What technologies are used in the development of computerized 'smart' systems?

Q15. What do you think about the security of data transfer due to the development of Internet of Things technology?

Q16. What affects will the internet of things (IoT) have on infrastructure and smart cities region?

Questionnaire for Interview taken with officials of Nepal Government involved in establishing smart city (Nepali Language)

१. स्मार्ट सिटीको अवधारणा र सम्भाव्यताको बारेमा तपाईंलाई के लाग्छ ?

२. स्मार्ट सिटीको विकासले नागरिकको जीवन शैलीमा सुधार ल्याउँदा त ?

३. प्रविधिले मानिसलाई कसरी परिवर्तन गराउछ प्राविधिक विकासले जीबनशैली मात्र सहज बनाउँछ त ?

४. नेपालमा चुस्त रुपमै स्मार्ट सिटी बनाउन सम्भव छ होला?

५. कुन प्रविधिले स्मार्ट सिटीबाट दिगो विकास गर्न हाबी गर्छ जस्तो लाग्छ तपाईलाई ?

६. ईन्टरनेट अफ थिङ्समा कि त्यस्ता तत्वहरु छन् जसले स्मार्ट सिटी बनाउन सक्छ ?

७. ईन्टरनेट अफ थिङ्समा सुरक्षाको प्रत्याभुति कसरी दिन सकिन्छ, सम्भव हुने स्थायी समाधान के- के हुन सक्छन ?

८. नेपालको अहिलेको पूर्वाधार स्मार्ट सिटी बनाउन काफी छ र ?

९. स्मार्ट सिटी बनाउन सरकारको के भूमिका हुन्छ ?

१०.स्मार्ट सिटी बनाउन हामी कहाँ के- के पूर्वाधारहरु उपलब्ध छन् , मलाई जानकारी गराउन सक्नु हुन्छ ?

११. धैरै क्षेत्रमा ईन्टरनेट अफ थिङ्सको प्रयोगले केही दशकमानै मानव सभ्यतामा परिवर्तन ल्याउला ?

१२. स्मार्ट सिटी बनाउने कुनै IoT Framework को बारेमा थाहा छ तपाईंलाई ?

१३. भविष्यको दिगो स्मार्ट सिटीका विशेषताहरु के- के होलान् ?

१४. कम्प्युटराइजड सिस्टमको विकासको लागि विशेषत: के प्रविधि बढी प्रयोगमा आउन सक्छ ?

१५. IoT प्रविधिले डाटा आदानप्रदान गर्दा आउनसक्ने सुरक्षासम्बन्धी खतराको बारेमा के भन्नु हुन्छ?

१६. ईन्टरनेट अफ थिङ्सको प्रयोगको पूर्वाधार र स्मार्ट सिटी बनाउने क्षेत्रमा कस्तो प्रभाव पार्ला ?

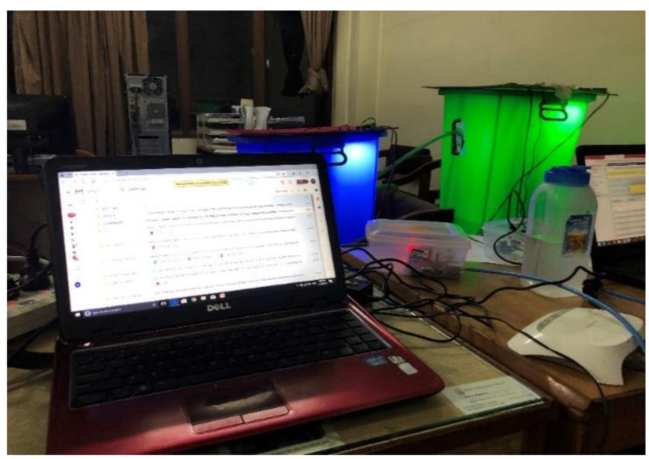
Some Snaps taken during interview period



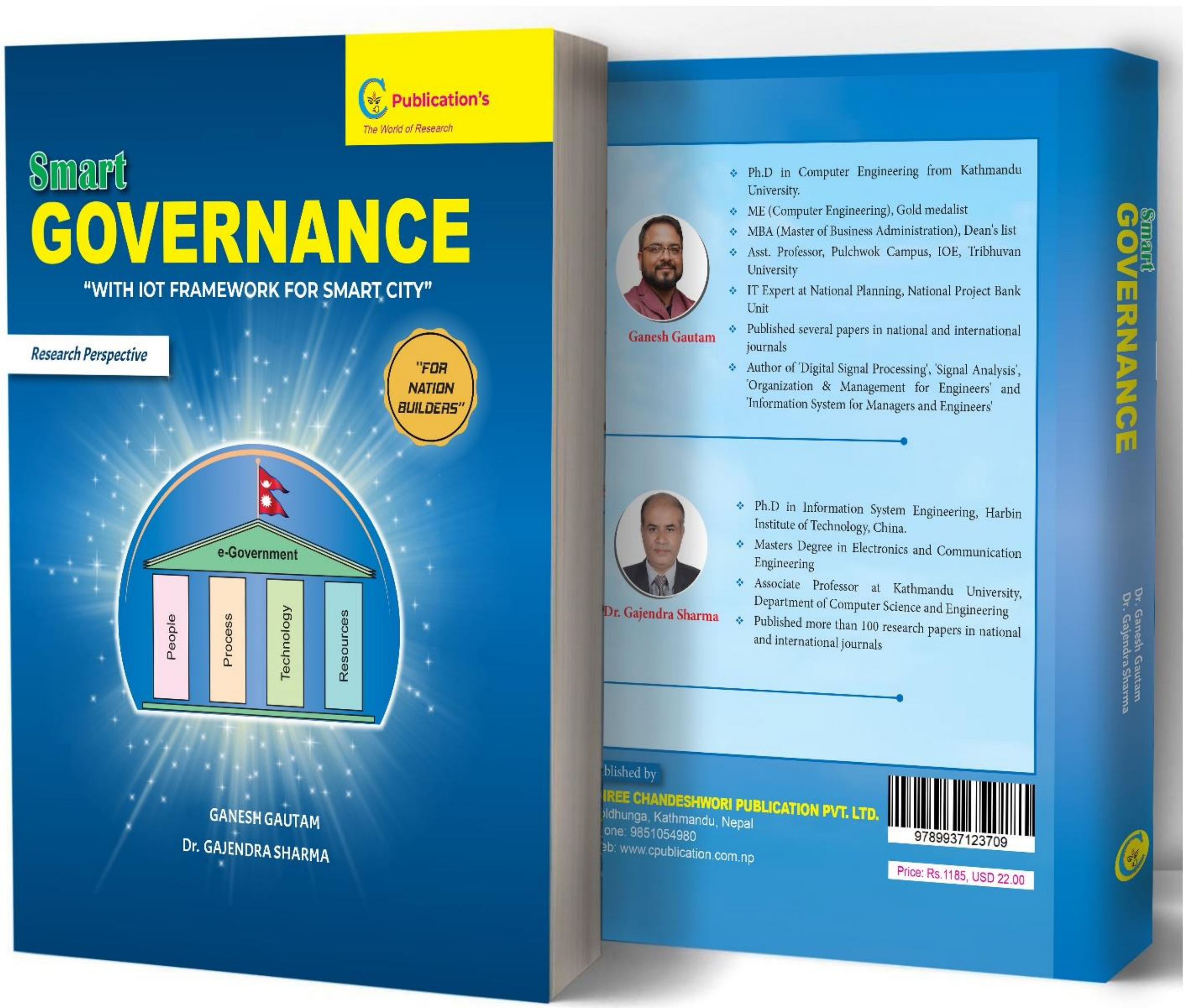




Miniature IoT Laboratory Setup (Some Snaps)



All research work and thesis has been plan to melt it down into a book



Patent Presentation at Department of Industry, Ministry of Trade and Commerce

Presentation of the research at National Planning Commission, Government of Nepal

Glimpses of participation in ICT-AES international conference

Received Best Paper Award in the Conference

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Internet Protocol Address Assignment in Internet of Things for Smart City Development

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Abstract

It has always been interesting to know how to assign Internet Protocol (IP) address to the sensors inherent in Internet of Things (IOT) for smart city. Though there are no such protocols or rules to allocate IP address it is evident that sensors needs IP to connect it to the server or cloud. Nowadays the concept of IPV6 is emerging, feeling that IP address in IPV4 is insufficient for each and every sensors present in the network. This paper aims to eliminate the confusion regarding the number of available addresses and its efficient usage. This research was carried out using a pair of ultrasonic sensors and these sensors were connected to the microcontroller and to the Ethernet port; eventually the sensor was connected to the router and the connection made available over the internet. The IP address is provided by the microcontroller for each sensor just to connect it to the router and to identify this sensor in the internet applications unique identification number can again be assigned; this task is also accomplished by programming or writing some lines of code in the microcontroller. The

Paper-II

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Article

Usage of IoT Framework in Water Supply Management for Smart City in Nepal

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Abstract: An efficient water supply management system can be one of the applications of the Internet of Things (IoT). Water is a basic physiological need, and smart management of water plays a significant role in a smart city. This paper focuses on a mathematical model and IoT framework that aid in developing a smart city. A framework is developed for water supply management. The efficiency of the water supply can be measured by monitoring leakage conditions, overflow of water, automatic meter reading and online bill payments, and water consumption status of households, community, state, and eventually the whole country as well as the automatic water supply line cut-off. The system where the IoT is being deployed consists of embedded hardware in which sensors and microcontrollers provide messages and gain feedback from each other with the help of the internet, and this process can not only be monitored but also can be controlled from a remote location. The developed framework addresses all these aspects and mathematical equations are used and formulated while developing the IoT application. The mathematical equations are concentrated on consumption level (CL), leakage reporting (LR), and bill amount (BA) based on consumption. These become the point of contact for deploying IoT and eventually a framework is developed. This framework can be useful not only in water supply management but also in the management of road traffic, pollution, garbage, home automation and so on. In a nutshell, this paper illustrates the usage

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Paper-III

ICT INFRASTRUCTURE ANALYSIS AND E-READINESS FOR SMART CITY DEVELOPMENT IN NEPAL

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Abstract

Though the concept of developing smart city in Nepal is burgeoning, the implementation phase and action plan is getting tedious. Inadequate research in the area and lack of essential infrastructure does not still allow Nepal to develop smart city. Many government officials and municipalities directors have a different understanding of what the smart city means. In this research an interview was carried out with the government officials, municipalities Mayors, Directors, and some IT and engineering professions to know about the underlying infrastructure and feasibility of smart city. Altogether 23 interviews as a part of qualitative research were conducted to find out the answer to know where the problem is to establishing efficient smart city. The result of the interview depicted that, lack of political initiation and commitment is the major problem, the second problem has been seen as low computer literacy, similarly lack of Public Private Partnership (PPPs) in establishing e-Government system, reluctancy in technological usage and advancement are the major hindrances to developing smart city. Knowledge regarding Internet of Things (IoT), low awareness of about e-Government system is found to be other barriers to develop the smart city.

Keywords: Internet of Things, Smart City, Public Private Partnership, Municipality, e-Government

1. Introduction

One of the preliminary steps to forming smart city is analyzing the existing infrastructure. Some cities like Dubai, Malta, Singapore and Kochi (India) are recently named as smart cities. Using the concepts of automation, communication technologies and internet of things the smart cities can be constructed. The main objective of creating the smart city is to minimize and manage the consumption of power and operational resources thereby reducing the overall operational cost [1]. This research work concentrates on using the Internet of Things as a major backbone in establishing smart cities. Sectors

Government of Nepal

National Planning Commission

Singha Durbar, Kathmandu, Nepal

Ref. No: 512

2021/03/12

Mr. Ganesh Gautam

Kathmandu University

Dulikhel, Kavre

Subject: Inclusion of your research work in National Project Bank, Government of Nepal

Dear Mr. Gautam and the team,

The National Project Bank is a system being used by National Planning Commission which is an apex advisory body of Government of Nepal. It is my pleasure to inform you that, the Government of Nepal has included your research work entitled "**Implementing Internet of Things (IoT) in Water Supply Management**" in National Project Bank and has planned to move forward to provide Government funding for your research work to implement in Nepal.

As per the presentation and report submitted on December 31, 2020 all of the concerned authorities were convinced and delighted with the novel work. I would like to congratulate all of your team members, Prof. Dr. Manish Pokharel, Prof. Dr. Ram Krishna Maharjan, Dr. Gajendra Sharma, Mr. Mahesh Singh Kathayat, Dr. Surendra Shrestha, Mr. Mukesh Regmi, and Mr, Bipin Thapa for your wonderful research work.

National Project Bank is sure that this project will accelerate the existing quality of life of the citizens by implementing your research work at National level.

Munaka Neupane

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Munaka Neupane

Program Director

National Project Bank

Government of Nepal National Planning Commission Singh Durbar, Kathmandu

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Interview taken with officials of Nepal Government involved in establishing smart city

<u>Data Collection sheet</u>

Q1. Do you think the concept of smart city will be feasible in Nepal?

SN	Respondent Name	Post held	Yes	No	Might be
1	Bashu Prasad Gautam	Ward Director Tarakeshwor-4	✓		
2	Narahari Gautam	Computer Engineer Tarakeshwor Municipality	✓		
3	Rameshwor Bohora	Mayor Tarakeshwor Municipality	✓		
4	Rabindra Rijal	Computer Engineer Parliament House		✓	
5	Kriti Nemkul	IT Specialist Lalitpur Metropolitan City			✓
6	Chiri Babu Maharjan	Mayor Lalitpur Metropolitan City	✓		
7	Dilli Ram Adhikari	Managing Director Nepal Telecom	✓		
8	Mukunda Rijal	Ward Director Kathmandu-16		✓	
9	Sunil Paudel	Executive Director, NITC	✓		
10	Dr. Bhaikaji Tiwari	KVDB, Chairman	✓		
11	Mr. Sabin Manandhar	Engineer, Ktm-14		✓	
12	Mr. Bidhya Sundar Shakya	Mayor, Kathmandu Municipality	✓		
13	Prof. Dr. Pushpa Raj Kadel	Vice- Chairman, National Planning Commission	✓		
14	Dirgha Narayan Aryal	Chairman, Arjunchaupari rural municipality, Syangja	✓		
15	Rohit Kumar Shah	Mayor, Gauradaha municipality, Jhapa			✓
16	Bhim Parajuli	Mayor, Biratnagar Metropolitan City	✓		
17	Ramesh Jimi	Mayor, Dharmadevi Municipality, Sankhuwasabha	✓		
18	Iwan Rai	Mayor, Halesi Tuwachung Municipality, Khotang	✓		
19	Santosh Chalise	Gokarneshwor Municipality, Kathmandu	✓		
20	Ramesh Maharjan	Kirtipur Municipality	✓		

Q2. Does the development of smart cities improve people's lives?

SN	Respondent Name	Post held	Yes	No	Might be
1	Bashu Prasad Gautam	Ward Director Tarakeshwor-4	✓		
2	Narahari Gautam	Computer Engineer Tarakeshwor Municipality	✓		
3	Rameshwor Bohora	Mayor Tarakeshwor Municipality	✓		
4	Rabindra Rijal	Computer Engineer Parliament House	✓		
5	Kriti Nemkul	IT Specialist Lalitpur Metropolitan City	✓		
6	Chiri Babu Maharjan	Mayor Lalitpur Metropolitan City	✓		
7	Dilli Ram Adhikari	Managing Director Nepal Telecom	✓		
8	Mukunda Rijal	Ward Director Kathmandu-16	✓		
9	Sunil Paudel	Executive Director, NITC	✓		
10	Dr. Bhaikaji Tiwari	KVDB, Chairman	✓		
11	Mr. Sabin Manandhar	Engineer, Ktm-14		✓	
12	Mr. Bidhya Sundar Shakya	Mayor, Kathmandu Municipality	✓		
13	Prof. Dr. Pushpa Raj Kadel	Vice- Chairman, National Planning Commission	✓		
14	Dirgha Narayan Aryal	Chairman, Arjunchaupari rural municipality, Syangja	✓		
15	Rohit Kumar Shah	Mayor, Gauradaha municipality, Jhapa		✓	
16	Bhim Parajuli	Mayor, Biratnagar Metropolitan City	✓		
17	Ramesh Jimi	Mayor, Dharmadevi Municipality, Sankhuwasabha	✓		
18	Iwan Rai	Mayor, Halesi Tuwachung Municipality, Khotang	✓		
19	Santosh Chalise	Gokarneshwor Municipality, Kathmandu	✓		
20	Ramesh Maharjan	Kirtipur Municipality	✓		

Q3. How does technology change people? Does technological development only make life easier for people?

SN	Respondent Name	Post held	Yes	No	Might be
1	Bashu Prasad Gautam	Ward Director Tarakeshwor-4		✓	
2	Narahari Gautam	Computer Engineer Tarakeshwor Municipality	✓		
3	Rameshwor Bohora	Mayor Tarakeshwor Municipality		✓	
4	Rabindra Rijal	Computer Engineer Parliament House		✓	
5	Kriti Nemkul	IT Specialist Lalitpur Metropolitan City	✓		
6	Chiri Babu Maharjan	Mayor Lalitpur Metropolitan City	✓		
7	Dilli Ram Adhikari	Managing Director Nepal Telecom		✓	
8	Mukunda Rijal	Ward Director Kathmandu-16		✓	
9	Sunil Paudel	Executive Director, NITC		✓	
10	Dr. Bhaikaji Tiwari	KVDB, Chairman		✓	
11	Mr. Sabin Manandhar	Engineer, Ktm-14		✓	
12	Mr. Bidhya Sundar Shakya	Mayor, Kathmandu Municipality	✓		
13	Prof. Dr. Pushpa Raj Kadel	Vice- Chairman, National Planning Commission		✓	
14	Dirgha Narayan Aryal	Chairman, Arjunchaupari rural municipality, Syangja		✓	
15	Rohit Kumar Shah	Mayor, Gauradaha municipality, Jhapa	✓		
16	Bhim Parajuli	Mayor, Biratnagar Metropolitan City		✓	
17	Ramesh Jimi	Mayor, Dharmadevi Municipality, Sankhuwasabha		✓	
18	Iwan Rai	Mayor, Halesi Tuwachung Municipality, Khotang		✓	
19	Santosh Chalise	Gokarneshwor Municipality, Kathmandu		✓	
20	Ramesh Maharjan	Kirtipur Municipality		✓	

SN	Respondent Name	Post held	Key words
1	Bashu Prasad Gautam	Ward Director Tarakeshwor-4	Lifestyle, Reduced Effort, Effective
2	Narahari Gautam	Computer Engineer Tarakeshwor Municipality	Time and effort

3	Rameshwor Bohora	Mayor Tarakeshwor Municipality	Transparency, Less Face to face delivery model
4	Rabindra Rijal	Computer Engineer Parliament House	Less Effort, Ease of service
5	Kriti Nemkul	IT Specialist Lalitpur Metropolitan City	Basic needs made easier
6	Chiri Babu Maharjan	Mayor Lalitpur Metropolitan City	Ease in Providing Service
7	Dilli Ram Adhikari	Managing Director Nepal Telecom	Internet usage in basic needs
8	Mukunda Rijal	Ward Director Kathmandu-16	NA
9	Sunil Paudel	Executive Director, NITC	Data about everything plays a vital role
10	Dr. Bhaikaji Tiwari	KVDB, Chairman	Adapt to recent technologies
11	Mr. Sabin Manandhar	Engineer, Ktm-14	Digital payment schemes
12	Mr. Bidhya Sundar Shakya	Mayor, Kathmandu Municipality	Internet usage in every field
13	Prof. Dr. Pushpa Raj Kadel	Vice- Chairman, National Planning Commission	IT in every household and business
14	Dirgha Narayan Aryal	Chairman, Arjunchaupari rural municipality, Syangja	e-system implementation all activities
15	Rohit Kumar Shah	Mayor, Gauradaha municipality, Jhapa	Ease the manual works
16	Bhim Parajuli	Mayor, Biratnagar Metropolitan City	Less effort in doing things
17	Ramesh Jimi	Mayor, Dharmadevi Municipality, Sankhuwasabha	Reduce manual work
18	Iwan Rai	Mayor, Halesi Tuwachung Municipality, Khotang	Internet reduce communication cost
19	Santosh Chalise	Gokarneshwor Municipality, Kathmandu	Rapid automation in many sectors
20	Ramesh Maharjan	Kirtipur Municipality	Technology usage in every field

Q4. Is it possible to build a fully autonomous smart city?

SN	Respondent Name	Post held	Yes	No	Might be
1	Bashu Prasad Gautam	Ward Director Tarakeshwor-4		✓	
2	Narahari Gautam	Computer Engineer Tarakeshwor Municipality		✓	
3	Rameshwor Bohora	Mayor	✓		

		Tarakeshwor Municipality			
4	Rabindra Rijal	Computer Engineer Parliament House		✓	
5	Kriti Nemkul	IT Specialist Lalitpur Metropolitan City			✓
6	Chiri Babu Maharjan	Mayor Lalitpur Metropolitan City	✓		
7	Dilli Ram Adhikari	Managing Director Nepal Telecom		✓	
8	Mukunda Rijal	Ward Director Kathmandu-16		✓	
9	Sunil Paudel	Executive Director, NITC			✓
10	Dr. Bhaikaji Tiwari	KVDB, Chairman	✓		
11	Mr. Sabin Manandhar	Engineer, Ktm-14	✓		
12	Mr. Bidhya Sundar Shakya	Mayor, Kathmandu Municipality		✓	
13	Prof. Dr. Pushpa Raj Kadel	Vice- Chairman, National Planning Commission	✓		
14	Dirgha Narayan Aryal	Chairman, Arjunchaupari rural municipality, Syangja			✓
15	Rohit Kumar Shah	Mayor, Gauradaha municipality, Jhapa	✓		
16	Bhim Parajuli	Mayor, Biratnagar Metropolitan City			✓
17	Ramesh Jimi	Mayor, Dharmadevi Municipality, Sankhuwasabha		✓	
18	Iwan Rai	Mayor, Halesi Tuwachung Municipality, Khotang		✓	
19	Santosh Chalise	Gokarneshwor Municipality, Kathmandu			✓
20	Ramesh Maharjan	Kirtipur Municipality	✓		

Q5. What technologies dominate in the field of smart sustainable development cities?

SN	Respondent Name	Post held	Key words
1	Bashu Prasad Gautam	Ward Director Tarakeshwor-4	Online Payment, e-commerce
2	Narahari Gautam	Computer Engineer Tarakeshwor Municipality	Online systems
3	Rameshwor Bohora	Mayor Tarakeshwor Municipality	Mobile based systems, IT enabling the municipality
4	Rabindra Rijal	Computer Engineer Parliament House	Smart phones, online systems
5	Kriti Nemkul	IT Specialist Lalitpur Metropolitan City	IoT
6	Chiri Babu Maharjan	Mayor	Internet enabled service

		Lalitpur Metropolitan City	
7	Dilli Ram Adhikari	Managing Director Nepal Telecom	Internet enabled service
8	Mukunda Rijal	Ward Director Kathmandu-16	NA
9	Sunil Paudel	Executive Director, NITC	Mobile Applications
10	Dr. Bhaikaji Tiwari	KVDB, Chairman	Advanced technologies
11	Mr. Sabin Manandhar	Engineer, Ktm-14	Online payment
12	Mr. Bidhya Sundar Shakya	Mayor, Kathmandu Municipality	Digital payment and smart services
13	Prof. Dr. Pushpa Raj Kadel	Vice- Chairman, National Planning Commission	Smart technologies
14	Dirgha Narayan Aryal	Chairman, Arjunchaupari rural municipality, Syangja	Data usage in cell phones
15	Rohit Kumar Shah	Mayor, Gauradaha municipality, Jhapa	Smart phones
16	Bhim Parajuli	Mayor, Biratnagar Metropolitan City	Smart phones
17	Ramesh Jimi	Mayor, Dharmadevi Municipality, Sankhuwasabha	Internet based services
18	Iwan Rai	Mayor, Halesi Tuwachung Municipality, Khotang	e-payment, penetration of digital devices
19	Santosh Chalise	Gokarneshwor Municipality, Kathmandu	Smart technologies
20	Ramesh Maharjan	Kirtipur Municipality	IT penetration in all sectors

Q6. What are the sustainability factors in IoT for smart city?

SN	Respondent Name	Post held	Factors
1	Bashu Prasad Gautam	Ward Director Tarakeshwor-4	No queue, Time saving
2	Narahari Gautam	Computer Engineer Tarakeshwor Municipality	Ease service providers
3	Rameshwor Bohora	Mayor Tarakeshwor Municipality	No queuing system, Municipality will be creative
4	Rabindra Rijal	Computer Engineer Parliament House	Maximum usage of IT, Low cost
5	Kriti Nemkul	IT Specialist Lalitpur Metropolitan City	Ease of use, Automation
6	Chiri Babu Maharjan	Mayor Lalitpur Metropolitan City	Hassle free service
7	Dilli Ram Adhikari	Managing Director Nepal Telecom	Low cost service
8	Mukunda Rijal	Ward Director Kathmandu-16	Citizen friendly services

9	Sunil Paudel	Executive Director, NITC	Maximum usage of IT
10	Dr. Bhaikaji Tiwari	KVDB, Chairman	Good Infrastructures
11	Mr. Sabin Manandhar	Engineer, Ktm-14	Low cost services
12	Mr. Bidhya Sundar Shakya	Mayor, Kathmandu Municipality	User friendly services
13	Prof. Dr. Pushpa Raj Kadel	Vice- Chairman, National Planning Commission	No queue, online services
14	Dirgha Narayan Aryal	Chairman, Arjunchaupari rural municipality, Syangja	Time saving services
15	Rohit Kumar Shah	Mayor, Gauradaha municipality, Jhapa	Service with some clicks
16	Bhim Parajuli	Mayor, Biratnagar Metropolitan City	No queue
17	Ramesh Jimi	Mayor, Dharmadevi Municipality, Sankhuwasabha	Ease of use
18	Iwan Rai	Mayor, Halesi Tuwachung Municipality, Khotang	Low cost services
19	Santosh Chalise	Gokarneshwor Municipality, Kathmandu	Less queue and hassle free services
20	Ramesh Maharjan	Kirtipur Municipality	Quick services

Q7. Can we solve security threats on IoT? If YES, then what are the possible permanent solutions?

SN	Respondent Name	Post held	Yes	No	Might be
1	Bashu Prasad Gautam	Ward Director Tarakeshwor-4			✓
2	Narahari Gautam	Computer Engineer Tarakeshwor Municipality	✓		
3	Rameshwor Bohora	Mayor Tarakeshwor Municipality			✓
4	Rabindra Rijal	Computer Engineer Parliament House	✓		
5	Kriti Nemkul	IT Specialist Lalitpur Metropolitan City	✓		
6	Chiri Babu Maharjan	Mayor Lalitpur Metropolitan City			✓
7	Dilli Ram Adhikari	Managing Director Nepal Telecom	✓		
8	Mukunda Rijal	Ward Director Kathmandu-16	NA		
9	Sunil Paudel	Executive Director, NITC	✓		
10	Dr. Bhaikaji Tiwari	KVDB, Chairman		✓	
11	Mr. Sabin Manandhar	Engineer, Ktm-14		✓	
12	Mr. Bidhya Sundar	Mayor, Kathmandu Municipality			✓

	Shakya				
13	Prof. Dr. Pushpa Raj Kadel	Vice- Chairman, National Planning Commission			✓
14	Dirgha Narayan Aryal	Chairman, Arjunchaupari rural municipality, Syangja	✓		
15	Rohit Kumar Shah	Mayor, Gauradaha municipality, Jhapa		✓	
16	Bhim Parajuli	Mayor, Biratnagar Metropolitan City			✓
17	Ramesh Jimi	Mayor, Dharmadevi Municipality, Sankhuwasabha			✓
18	Iwan Rai	Mayor, Halesi Tuwachung Municipality, Khotang			✓
19	Santosh Chalise	Gokarneshwor Municipality, Kathmandu			✓
20	Ramesh Maharjan	Kirtipur Municipality			✓

SN	Respondent Name	Post held	Possible Solutions
1	Bashu Prasad Gautam	Ward Director Tarakeshwor-4	Strong policies
2	Narahari Gautam	Computer Engineer Tarakeshwor Municipality	High level cryptography
3	Rameshwor Bohora	Mayor Tarakeshwor Municipality	Punitive measures
4	Rabindra Rijal	Computer Engineer Parliament House	Encyption and cryptography
5	Kriti Nemkul	IT Specialist Lalitpur Metropolitan City	3AES encryption
6	Chiri Babu Maharjan	Mayor Lalitpur Metropolitan City	Strong policies and Act
7	Dilli Ram Adhikari	Managing Director Nepal Telecom	Cryptographic measures
8	Mukunda Rijal	Ward Director Kathmandu-16	Strong punishment
9	Sunil Paudel	Executive Director, NITC	Cryptographic measures
10	Dr. Bhaikaji Tiwari	KVDB, Chairman	Strong policies
11	Mr. Sabin Manandhar	Engineer, Ktm-14	Strong policies
12	Mr. Bidhya Sundar Shakya	Mayor, Kathmandu Municipality	Punishment provisions
13	Prof. Dr. Pushpa Raj Kadel	Vice- Chairman, National Planning Commission	Strong rules and regulation
14	Dirgha Narayan Aryal	Chairman, Arjunchaupari rural municipality, Syangja	Legal procedures
15	Rohit Kumar Shah	Mayor, Gauradaha municipality, Jhapa	Multilevel security tires
16	Bhim Parajuli	Mayor, Biratnagar Metropolitan	Usage of cryptographic

		City	measures
17	Ramesh Jimi	Mayor, Dharmadevi Municipality, Sankhuwasabha	Strong policies formulation
18	Iwan Rai	Mayor, Halesi Tuwachung Municipality, Khotang	Don't know
19	Santosh Chalise	Gokarneshwor Municipality, Kathmandu	Punitive measures for breaching the security
20	Ramesh Maharjan	Kirtipur Municipality	Maintain high level of security by hiring professionals

Q8. Is the current technological infrastructural status adequate to develop smart city?

SN	Respondent Name	Post held	Yes	No	Might be
1	Bashu Prasad Gautam	Ward Director Tarakeshwor-4		✓	
2	Narahari Gautam	Computer Engineer Tarakeshwor Municipality		✓	
3	Rameshwor Bohora	Mayor Tarakeshwor Municipality			✓
4	Rabindra Rijal	Computer Engineer Parliament House		✓	
5	Kriti Nemkul	IT Specialist Lalitpur Metropolitan City		✓	
6	Chiri Babu Maharjan	Mayor Lalitpur Metropolitan City	✓		
7	Dilli Ram Adhikari	Managing Director Nepal Telecom			✓
8	Mukunda Rijal	Ward Director Kathmandu-16		✓	
9	Sunil Paudel	Executive Director, NITC		✓	
10	Dr. Bhaikaji Tiwari	KVDB, Chairman		✓	
11	Mr. Sabin Manandhar	Engineer, Ktm-14		✓	
12	Mr. Bidhya Sundar Shakya	Mayor, Kathmandu Municipality			✓
13	Prof. Dr. Pushpa Raj Kadel	Vice- Chairman, National Planning Commission		✓	
14	Dirgha Narayan Aryal	Chairman, Arjunchaupari rural municipality, Syangja			✓
15	Rohit Kumar Shah	Mayor, Gauradaha municipality, Jhapa		✓	
16	Bhim Parajuli	Mayor, Biratnagar Metropolitan City		✓	
17	Ramesh Jimi	Mayor, Dharmadevi Municipality, Sankhuwasabha			✓
18	Iwan Rai	Mayor, Halesi Tuwachung		✓	

		Municipality, Khotang			
19	Santosh Chalise	Gokarneshwor Municipality, Kathmandu			✓
20	Ramesh Maharjan	Kirtipur Municipality		✓	

Q9. What should be the role of government in smart city?

SN	Respondent Name	Post held	keywords
1	Bashu Prasad Gautam	Ward Director Tarakeshwor-4	Political Commitment
2	Narahari Gautam	Computer Engineer Tarakeshwor Municipality	Initiation from Govt. Side
3	Rameshwor Bohora	Mayor Tarakeshwor Municipality	Plans, policies and encouragement
4	Rabindra Rijal	Computer Engineer Parliament House	Project initiation, Budgeting
5	Kriti Nemkul	IT Specialist Lalitpur Metropolitan City	Political Commitment
6	Chiri Babu Maharjan	Mayor Lalitpur Metropolitan City	Good Governance, Quick decision
7	Dilli Ram Adhikari	Managing Director Nepal Telecom	Initiation of innovative projects and financing
8	Mukunda Rijal	Ward Director Kathmandu-16	Good Governance
9	Sunil Paudel	Executive Director, NITC	Citizen friendly plans and policies formulation
10	Dr. Bhaikaji Tiwari	KVDB, Chairman	Release funds quickly, to not stop the work
11	Mr. Sabin Manandhar	Engineer, Ktm-14	Promote IT based projects
12	Mr. Bidhya Sundar Shakya	Mayor, Kathmandu Municipality	Raise awareness about deriving benefits from IT
13	Prof. Dr. Pushpa Raj Kadel	Vice- Chairman, National Planning Commission	Awareness programs
14	Dirgha Narayan Aryal	Chairman, Arjunchaupari rural municipality, Syangja	Political commitment
15	Rohit Kumar Shah	Mayor, Gauradaha municipality, Jhapa	Raise awareness
16	Bhim Parajuli	Mayor, Biratnagar Metropolitan City	Promote innovations in IT
17	Ramesh Jimi	Mayor, Dharmadevi Municipality, Sankhuwasabha	Political and financial support for innovators
18	Iwan Rai	Mayor, Halesi Tuwachung Municipality, Khotang	Support development and usage of IT in rural

			areas also
19	Santosh Chalise	Gokarneshwor Municipality, Kathmandu	Formulate policies to stop brain drain especially students of IT
20	Ramesh Maharjan	Kirtipur Municipality	Raise awareness

Q10. Can you say me about the available infrastructure to implement smart city?

SN	Respondent Name	Post held	Available Assets
1	Bashu Prasad Gautam	Ward Director Tarakeshwor-4	Computer Literacy, Internet availability
2	Narahari Gautam	Computer Engineer Tarakeshwor Municipality	Only good internet, Nothing else
3	Rameshwor Bohora	Mayor Tarakeshwor Municipality	Genius IT people, Internet
4	Rabindra Rijal	Computer Engineer Parliament House	Don’t know
5	Kriti Nemkul	IT Specialist Lalitpur Metropolitan City	Internet Availability, Network servers
6	Chiri Babu Maharjan	Mayor Lalitpur Metropolitan City	Internet services, Smart phones
7	Dilli Ram Adhikari	Managing Director Nepal Telecom	Internet and smart phones
8	Mukunda Rijal	Ward Director Kathmandu-16	Mobile phones
9	Sunil Paudel	Executive Director, NITC	High Internet penetration
10	Dr. Bhaikaji Tiwari	KVDB, Chairman	Smart city initiation, budgeting
11	Mr. Sabin Manandhar	Engineer, Ktm-14	NA
12	Mr. Bidhya Sundar Shakya	Mayor, Kathmandu Municipality	Good internet
13	Prof. Dr. Pushpa Raj Kadel	Vice- Chairman, National Planning Commission	Reduced load shedding and high internet penetration
14	Dirgha Narayan Aryal	Chairman, Arjunchaupari rural municipality, Syangja	People being aware of internet usage
15	Rohit Kumar Shah	Mayor, Gauradaha municipality, Jhapa	Usage of mobile phones even in rural areas
16	Bhim Parajuli	Mayor, Biratnagar Metropolitan City	People being technology friendly
17	Ramesh Jimi	Mayor, Dharmadevi Municipality, Sankhuwasabha	Reduced load shedding and usage of smart phones in rural areas
18	Iwan Rai	Mayor, Halesi Tuwachung Municipality, Khotang	Usage of mobile phones in rural areas

19	Santosh Chalise	Gokarneshwor Municipality, Kathmandu	Massive use of digital payment and internet penetration
20	Ramesh Maharjan	Kirtipur Municipality	People being aware of internet usage

Q11. Do you think human civilization changes in a few decades due to usage of IoT in several sectors? How?

SN	Respondent Name	Post held	Yes	No	Might be
1	Bashu Prasad Gautam	Ward Director Tarakeshwor-4			✓
2	Narahari Gautam	Computer Engineer Tarakeshwor Municipality			✓
3	Rameshwor Bohora	Mayor Tarakeshwor Municipality	✓		
4	Rabindra Rijal	Computer Engineer Parliament House		✓	
5	Kriti Nemkul	IT Specialist Lalitpur Metropolitan City	✓		
6	Chiri Babu Maharjan	Mayor Lalitpur Metropolitan City	✓		
7	Dilli Ram Adhikari	Managing Director Nepal Telecom	✓		
8	Mukunda Rijal	Ward Director Kathmandu-16		✓	
9	Sunil Paudel	Executive Director, NITC	✓		
10	Dr. Bhaikaji Tiwari	KVDB, Chairman			✓
11	Mr. Sabin Manandhar	Engineer, Ktm-14			✓
12	Mr. Bidhya Sundar Shakya	Mayor, Kathmandu Municipality	✓		
13	Prof. Dr. Pushpa Raj Kadel	Vice- Chairman, National Planning Commission	✓		
14	Dirgha Narayan Aryal	Chairman, Arjunchaupari rural municipality, Syangja			✓
15	Rohit Kumar Shah	Mayor, Gauradaha municipality, Jhapa		✓	
16	Bhim Parajuli	Mayor, Biratnagar Metropolitan City			✓
17	Ramesh Jimi	Mayor, Dharmadevi Municipality, Sankhuwasabha			✓
18	Iwan Rai	Mayor, Halesi Tuwachung Municipality, Khotang			✓
19	Santosh Chalise	Gokarneshwor Municipality, Kathmandu	✓		
20	Ramesh Maharjan	Kirtipur Municipality	✓		

SN	Respondent Name	Post held	keywords
1	Bashu Prasad Gautam	Ward Director Tarakeshwor-4	Working Procedure Changes
2	Narahari Gautam	Computer Engineer Tarakeshwor Municipality	Changes in working style
3	Rameshwor Bohora	Mayor Tarakeshwor Municipality	Less corruption, Ethical behavior development
4	Rabindra Rijal	Computer Engineer Parliament House	Changes in buying and selling activities
5	Kriti Nemkul	IT Specialist Lalitpur Metropolitan City	Quick Technology adaptation
6	Chiri Babu Maharjan	Mayor Lalitpur Metropolitan City	Good Governance
7	Dilli Ram Adhikari	Managing Director Nepal Telecom	Transparency
8	Mukunda Rijal	Ward Director Kathmandu-16	Less corruption, good governance
9	Sunil Paudel	Executive Director, NITC	Efficient service delivery
10	Dr. Bhaikaji Tiwari	KVDB, Chairman	Build Ethical behavior in citizens
11	Mr. Sabin Manandhar	Engineer, Ktm-14	Ease in working
12	Mr. Bidhya Sundar Shakya	Mayor, Kathmandu Municipality	Time saving approaches gets emerged
13	Prof. Dr. Pushpa Raj Kadel	Vice- Chairman, National Planning Commission	High transparency
14	Dirgha Narayan Aryal	Chairman, Arjunchaupari rural municipality, Syangja	Less corruption
15	Rohit Kumar Shah	Mayor, Gauradaha municipality, Jhapa	Ethical behavior development due to transparency in working
16	Bhim Parajuli	Mayor, Biratnagar Metropolitan City	Changes in daily routine due to use of smart services
17	Ramesh Jimi	Mayor, Dharmadevi Municipality, Sankhuwasabha	Smart services
18	Iwan Rai	Mayor, Halesi Tuwachung Municipality, Khotang	Most of the work done using smart phones
19	Santosh Chalise	Gokarneshwor Municipality, Kathmandu	Smart services
20	Ramesh Maharjan	Kirtipur Municipality	Maintained transparency

Q12. Do you know about any Framework for the IoT based Smart City Applications?

SN	Respondent Name	Post held	Yes	No
1	Bashu Prasad Gautam	Ward Director Tarakeshwor-4		✓

2	Narahari Gautam	Computer Engineer Tarakeshwor Municipality		✓
3	Rameshwor Bohora	Mayor Tarakeshwor Municipality		✓
4	Rabindra Rijal	Computer Engineer Parliament House		✓
5	Kriti Nemkul	IT Specialist Lalitpur Metropolitan City	✓	
6	Chiri Babu Maharjan	Mayor Lalitpur Metropolitan City		✓
7	Dilli Ram Adhikari	Managing Director Nepal Telecom		✓
8	Mukunda Rijal	Ward Director Kathmandu-16		✓
9	Sunil Paudel	Executive Director, NITC	✓	
10	Dr. Bhaikaji Tiwari	KVDB, Chairman		✓
11	Mr. Sabin Manandhar	Engineer, Ktm-14		✓
12	Mr. Bidhya Sundar Shakya	Mayor, Kathmandu Municipality		✓
13	Prof. Dr. Pushpa Raj Kadel	Vice- Chairman, National Planning Commission		✓
14	Dirgha Narayan Aryal	Chairman, Arjunchaupari rural municipality, Syangja		✓
15	Rohit Kumar Shah	Mayor, Gauradaha municipality, Jhapa		✓
16	Bhim Parajuli	Mayor, Biratnagar Metropolitan City		✓
17	Ramesh Jimi	Mayor, Dharmadevi Municipality, Sankhuwasabha		✓
18	Iwan Rai	Mayor, Halesi Tuwachung Municipality, Khotang		✓
19	Santosh Chalise	Gokarneshwor Municipality, Kathmandu		✓
20	Ramesh Maharjan	Kirtipur Municipality		✓

Q13.What are the characteristics of a sustainable future smart city?

SN	Respondent Name	Post held	Characteristics
1	Bashu Prasad Gautam	Ward Director Tarakeshwor-4	Neat, Clean, IT usage, no physical queue
2	Narahari Gautam	Computer Engineer Tarakeshwor Municipality	Work done by smart phone
3	Rameshwor Bohora	Mayor Tarakeshwor Municipality	Very efficient municipality, many works done in a day, No pending jobs
4	Rabindra Rijal	Computer Engineer	Efficiency in getting

		Parliament House	service
5	Kriti Nemkul	IT Specialist Lalitpur Metropolitan City	Online Billing, Ease in Communication, Electricity, Transportation will be easy
6	Chiri Babu Maharjan	Mayor Lalitpur Metropolitan City	IT enabled activities
7	Dilli Ram Adhikari	Managing Director Nepal Telecom	Ease in Communication, and all other services
8	Mukunda Rijal	Ward Director Kathmandu-16	NA
9	Sunil Paudel	Executive Director, NITC	IT in almost all activities
10	Dr. Bhaikaji Tiwari	KVDB, Chairman	Efficient structural infrastructure
11	Mr. Sabin Manandhar	Engineer, Ktm-14	IT in every services
12	Mr. Bidhya Sundar Shakya	Mayor, Kathmandu Municipality	Innovation in every field
13	Prof. Dr. Pushpa Raj Kadel	Vice- Chairman, National Planning Commission	IT enabled services
14	Dirgha Narayan Aryal	Chairman, Arjunchaupari rural municipality, Syangja	Less effort, high efficiency, low cost services
15	Rohit Kumar Shah	Mayor, Gauradaha municipality, Jhapa	User friendly e-services, secure digital payment
16	Bhim Parajuli	Mayor, Biratnagar Metropolitan City	Getting efficient service
17	Ramesh Jimi	Mayor, Dharmadevi Municipality, Sankhuwasabha	High efficiency, less effort
18	Iwan Rai	Mayor, Halesi Tuwachung Municipality, Khotang	Quality of life of citizens
19	Santosh Chalise	Gokarneshwor Municipality, Kathmandu	Efficient and quality of service delivery to citizens
20	Ramesh Maharjan	Kirtipur Municipality	Efficient service delivery to citizens

Q14. What technologies are used in the development of computerized 'smart' systems?

SN	Respondent Name	Post held	Technologies
1	Bashu Prasad Gautam	Ward Director Tarakeshwor-4	Mobile phones, good internet
2	Narahari Gautam	Computer Engineer Tarakeshwor Municipality	IoT, G2C services
3	Rameshwor Bohora	Mayor Tarakeshwor Municipality	Database systems, maximum use of mobile

			phones
4	Rabindra Rijal	Computer Engineer Parliament House	IoT devices
5	Kriti Nemkul	IT Specialist Lalitpur Metropolitan City	IoT devices
6	Chiri Babu Maharjan	Mayor Lalitpur Metropolitan City	Internet based services, Mobile Applications
7	Dilli Ram Adhikari	Managing Director Nepal Telecom	Internet in all sectors
8	Mukunda Rijal	Ward Director Kathmandu-16	Computer in all places where we deliver service
9	Sunil Paudel	Executive Director, NITC	IT in every sectors, Mobile Apps
10	Dr. Bhaikaji Tiwari	KVDB, Chairman	Automatized services
11	Mr. Sabin Manandhar	Engineer, Ktm-14	NA
12	Mr. Bidhya Sundar Shakya	Mayor, Kathmandu Municipality	NA
13	Prof. Dr. Pushpa Raj Kadel	Vice- Chairman, National Planning Commission	Mobile Applications, smart services
14	Dirgha Narayan Aryal	Chairman, Arjunchaupari rural municipality, Syangja	Digital data storage services
15	Rohit Kumar Shah	Mayor, Gauradaha municipality, Jhapa	NA
16	Bhim Parajuli	Mayor, Biratnagar Metropolitan City	NA
17	Ramesh Jimi	Mayor, Dharmadevi Municipality, Sankhuwasabha	Internet based services
18	Iwan Rai	Mayor, Halesi Tuwachung Municipality, Khotang	NA
19	Santosh Chalise	Gokarneshwor Municipality, Kathmandu	Services using mobile applications
20	Ramesh Maharjan	Kirtipur Municipality	Mobile applications

Q15. What do you think about the security of data transfer due to the development of Internet of Things technology?

SN	Respondent Name	Post held	Critical	Not Critical	Don't know
1	Bashu Prasad Gautam	Ward Director Tarakeshwor-4			✓
2	Narahari Gautam	Computer Engineer Tarakeshwor Municipality	✓		
3	Rameshwor Bohora	Mayor Tarakeshwor Municipality	✓		
4	Rabindra Rijal	Computer Engineer Parliament House	✓		

5	Kriti Nemkul	IT Specialist Lalitpur Metropolitan City	✓		
6	Chiri Babu Maharjan	Mayor Lalitpur Metropolitan City	✓		
7	Dilli Ram Adhikari	Managing Director Nepal Telecom	✓		
8	Mukunda Rijal	Ward Director Kathmandu-16	✓		
9	Sunil Paudel	Executive Director, NITC	✓		
10	Dr. Bhaikaji Tiwari	KVDB, Chairman			✓
11	Mr. Sabin Manandhar	Engineer, Ktm-14	✓		
12	Mr. Bidhya Sundar Shakya	Mayor, Kathmandu Municipality	✓		
13	Prof. Dr. Pushpa Raj Kadel	Vice- Chairman, National Planning Commission	✓		
14	Dirgha Narayan Aryal	Chairman, Arjunchaupari rural municipality, Syangja	✓		
15	Rohit Kumar Shah	Mayor, Gauradaha municipality, Jhapa	✓		
16	Bhim Parajuli	Mayor, Biratnagar Metropolitan City			✓
17	Ramesh Jimi	Mayor, Dharmadevi Municipality, Sankhuwasabha			✓
18	Iwan Rai	Mayor, Halesi Tuwachung Municipality, Khotang	✓		
19	Santosh Chalise	Gokarneshwor Municipality, Kathmandu	✓		
20	Ramesh Maharjan	Kirtipur Municipality	✓		

Q16. What affects will the internet of things (IoT) have on infrastructure and smart cities region?

SN	Respondent Name	Post held	Positive	Negative	No Effect
1	Bashu Prasad Gautam	Ward Director Tarakeshwor-4	✓		
2	Narahari Gautam	Computer Engineer Tarakeshwor	✓		

		Municipality			
3	Rameshwor Bohora	Mayor Tarakeshwor Municipality	✓		
4	Rabindra Rijal	Computer Engineer Parliament House			✓
5	Kriti Nemkul	IT Specialist Lalitpur Metropolitan City	✓	✓	
6	Chiri Babu Maharjan	Mayor Lalitpur Metropolitan City	✓	✓	
7	Dilli Ram Adhikari	Managing Director Nepal Telecom	✓	✓	
8	Mukunda Rijal	Ward Director Kathmandu-16			✓
9	Sunil Paudel	Executive Director, NITC	✓		
10	Dr. Bhaikaji Tiwari	KVDB, Chairman	✓		
11	Mr. Sabin Manandhar	Engineer, Ktm-14	✓	✓	
12	Mr. Bidhya Sundar Shakya	Mayor, Kathmandu Municipality	✓		
13	Prof. Dr. Pushpa Raj Kadel	Vice- Chairman, National Planning Commission	✓	✓	
14	Dirgha Narayan Aryal	Chairman, Arjunchaupari rural municipality, Syangja	✓		
15	Rohit Kumar Shah	Mayor, Gauradaha municipality, Jhapa	✓	✓	
16	Bhim Parajuli	Mayor, Biratnagar Metropolitan City	✓		
17	Ramesh Jimi	Mayor, Dharmadevi Municipality, Sankhuwasabha	✓		
18	Iwan Rai	Mayor, Halesi Tuwachung Municipality, Khotang	✓		
19	Santosh Chalise	Gokarneshwor Municipality, Kathmandu	✓		
20	Ramesh Maharjan	Kirtipur Municipality	✓		