ISSN No:-2456-2165

A Comparative Study on Smart Mobility IoT Architectures

Sushant Paudel
Department of Computer Science & Engineering
Kathmandu University (KU) Dhulikhel, Nepal

Abstract:- Smart city trends have been growing dramatically in today's scenario. So, to fulfil the needs of smart city trends many hardware and software are being developed. This paper discusses the current status of architectural designs, hardware and software designs in smart mobility. Smart mobility is also one of the classes that fall under Smart city infrastructure. So, we are going to discuss different IoT-based architectures for Smart Mobility. There are many Internet of Things (IoT) based architectures that are being made for Smart mobility. But, each architecture has some flaws and are only supporting a small part of the smart mobility trend. So, in this paper different architectures are reviewed and compared for the pros and cons. By analyzing the information gathered from different smart mobility services we propose an architecture which is feasible and with the pros of most of the previous architectures. Also, this architecture is built on a blockchain network so the network is secure and private which is one of the greeted problems faced in the IoT ecosystem.

Keywords:- *Smart Mobility, Architecture, Comparison.*

I. INTRODUCTION

Smart city trends have been growing dramatically in today's scenario. So, to fulfil the needs of smart city trends many hardware and software are being developed. This paper discusses the current status of architectural designs, hardware and software designs in smart mobility. Smart mobility is also one of the classes that fall under Smart city infrastructure. So, we are going to discuss different IoT-based architectures for Smart Mobility.

There are many Internet of Things (IoT) based architectures that are being made for Smart mobility. But, each architecture has some flaws and are only supporting a small part of the smart mobility trend. So, knowing the IoT architecture that will suffice the overall requirements in daily use has been pretty difficult. Identification of the proper architecture in Smart mobility for today's use will be very beneficial in the long run too. The objective of the comparison of the different IoT architectures is to find an overall architecture that will fulfil our needs. As we know that the growth of cloud computing has brought many devices closer than they were before but, due to security measures it has been difficult to implement the technology right away in the field. So, the research question we are trying to answer is:

- *How to develop a complete IoT architecture that will be used in Smart Mobility?*

Architecture comparison has many factors associated with it. The network technology, the device technology, implementation feasibility and more. We will discuss all the main factors that comprise the IoT architecture and propose a complete architecture which can be used and can be scaled properly if a different kind of IoT device is introduced in the network.

In this paper, Section II discusses the reference IoT architecture from [1] which will be used to propose the architecture, Section III discuss the past work related to Smart Mobility and IoT devices, and Section IV will an evaluation of the different architecture from the past works, and Section V will be the proposed architecture and finally, Section VI will be the conclusion, limitations and future work of this research.

II. WHAT IS IoT

Internet of Things (IoT) can be defined as the network of different interconnected devices which shares the same network and provides connectivity to one another in the network from any place at any time within the same network. The IoT is considered one of the great innovations in the 21st century because of the growth of technology. The use of technology not only in the digital world but also in the physical world brought the rise of IoT technology. The summarized reference architecture from [1] is shown in Figure 1.

ISSN No:-2456-2165

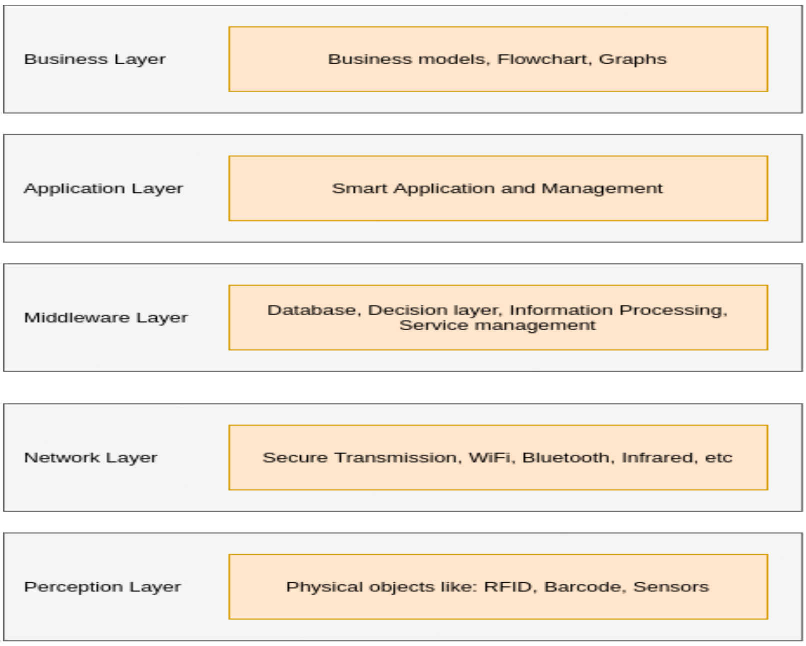

Fig. 1: The IoT Reference Architecture

A. Perception Layer

This layer can also be defined as the 'Device Layer'. This layer consists of the different IoT devices that can also be referred to as the sensors which capture the data from the environment and are sent to the database over the network on which the device is connected. Some examples of devices are RFID sensors, Barcode scanners, Temperature sensors, etc.

B. Network Layer

The network layer comprises the transmission line for the IoT ecosystem so, it can also be referred to as the 'Transmission Layer'. This layer handles all the transmissions between the devices connected to the network. This layer also ensures the security of the network. So, the most crucial part of the IoT is the network layer, because without the network the sensors will capture real-time data but, it will not be saved to the database for analysis purposes.

C. Middleware Layer

The software or can say the analysis part of the IoT is this layer. This layer ensures the data transmitted over the network is saved in the database and used for further processing. The main purpose of this layer is to act as a backend gateway for the IoT system and for information processing.

D. Application Layer

This layer works as the presentation layer for the IoT system which is used to monitor the devices and make some decisions on the lower level.

E. Business Layer

This is the topmost level in the IoT system because this layer monitors the smart application, and the users and analyses the data from the devices to make business decisions. They also create a flow chart for further plans.

The overall IoT ecosystem is the sensors capturing data which is stored in the database to be analyzed to make further business decisions. So, the IoT works as a barrier in the physical world and digital world to make out life easier.

III. RELATED WORK

IoT devices have been the revolutionary part of Smart mobility. So, there has already many projects which have been already developed in the Smart mobility field. So, this section discusses the different architecture and documents which will be the reference to propose the final architecture.

A. Intelligent transport systems in urban areas.

Transportation is one of the most important parts of smart city planning. According to [2], the urban population is expected to grow from 54% worldwide to 66% by 2050. This amount of urban population is a large amount and it contributes more to urban smart mobility. So, this paper is the analysis of 71 papers published from 2006 to 2014 which study the different research methods and application fields. The purpose of this paper is to provide an in-depth review of the papers on the role of Information technology in supporting urban smart mobility for information accuracy and decision-making speed. The author found out that most urban mobility includes both freight and people transport so, in urban areas these vehicles have a negative affect on the overall traffic situation. So, if we could implement ICT in urban smart mobility then the problem of traffic will be drastically improved.

B. Map-based platform for Smart Mobility Services

Smart and Social move(S2 move) is a term coined in [3] which is the term used in smart mobility. The S2 Move project proposes an architecture which is used to collect data from various sources and process real-time data to improve mobility services. In [4], the author is proposing a map-based web platform which is a part of the S2 move project and is used to provide smart mobility services. The aim of this paper is to use map-based data so that it would have a

ISSN No:-2456-2165

geographical representation of data which will allow for easy manipulation.

The architecture proposed by [4] is shown in Figure 2. This architecture has 3 layers, the presentation layer, the core layer and the data layer. The presentation layer consists of the application which is used to monitor the services and analyze the data. The core layer consists of the business logic for the system. The data layer consists of the data that is acquired from various sources like mobile phones, sensors, etc. The main component is the Core layer in this architecture. This layer not only consists of the business logic of the system, but also consists of different systems like smart parking, fleet management, warning management, and traffic monitoring. These individual systems are integrated into the architecture which will provide better insights into the analysis of the data and can be used to make better decisions in the long run.

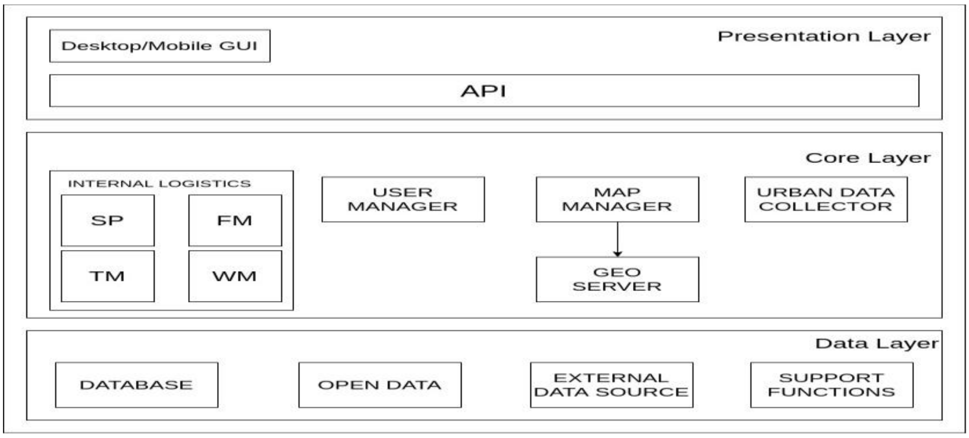

Fig. 2: Map-based web platform architecture

C. Architecture for parking management in cities

The main problem we still face in mobility is the parking spaces in urban areas. Vehicles are growing at a rapid rate and the space available to park those vehicles are decreasing simultaneously. So, without proper parking management in city areas, the traffic will be worse. In [5], the author has proposed an architecture for parking management in smart cities and the architecture is shown in Figure 3.

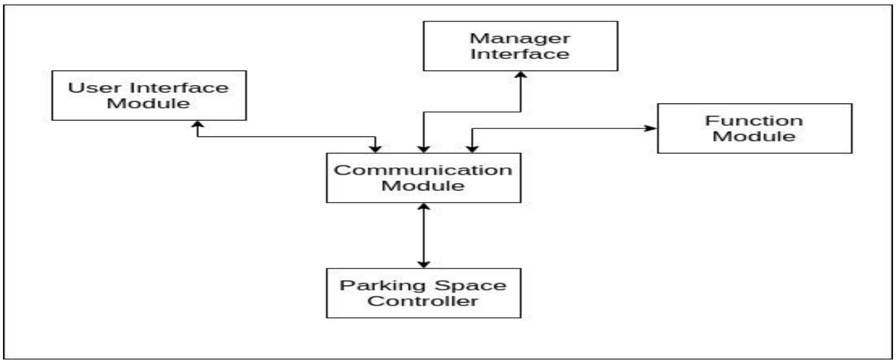

Fig. 3: Block diagram for Parking Management in Smart Cities

The architecture proposed in [5], manages vacant spaces for parking with the help of different sensors and wireless communication. With the help of automation, there is less fault compared to human involvement. The different components in the architecture are, the parking space controller which used different sensors to identify the parking space, and the user interface module is a module that communicated with the user for accounting, reservation, cancellation and billing. The communication module is the network underlying the parking management system, the function module is the business layer in this system which contains the business logic and database, and the management interface is the application which is used to monitor the devices, sensors, and customers in the parking management system. All the components are integrated and work simultaneously to make business decisions.

D. Vehicular Social Networks

There are many vehicles and users connected to the internet and using this data to improve the situation of mobility services is presented in the paper, [6]. In this paper, the existing communication systems used by the people and the vehicles which are connected to the internet with their sensors are integrated to form a vehicular social network(VSN). With the VSN, they can incorporate the social relationship among the users and the network of communication of the vehicle users which will provide a proper result upon analysis because the social network and internet of vehicles(IoVs) are interconnected. The block diagram of the VSN can be shown in Figure 4.

ISSN No:-2456-2165

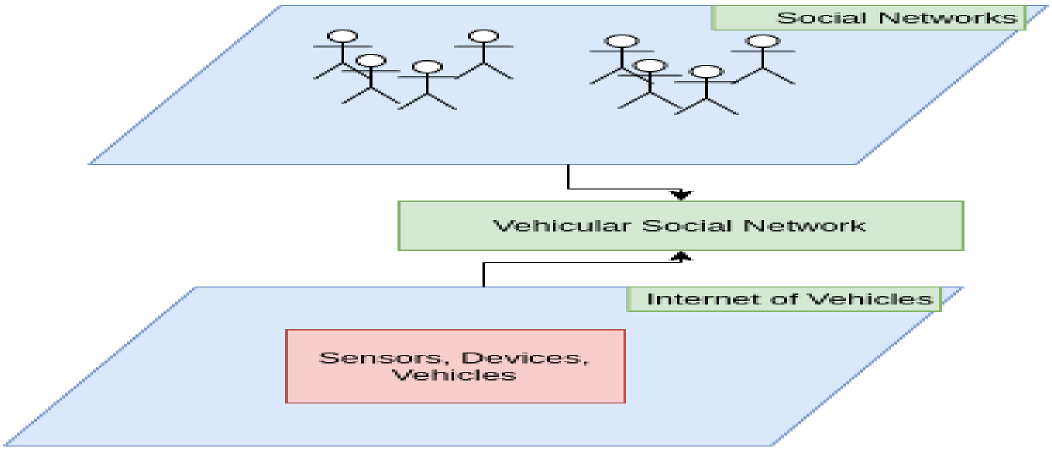

Fig. 4: Block diagram of Vehicular Social Network

This architecture can be used to detect anomalies by inferring traffic prediction and congestion alleviation through the analysis of the temporal and spatial data. This network acquires data from social networks and IoVs to a large extent. So, some limitations of this network are the big trajectory analysis, trust, security and, privacy. This type of network must be implemented on a large scale and only it can predict properly so, it is very difficult to make the users trust this system right away.

E. A Taxonomy for planning and designing smart mobility services

For the implementation of smart mobility services should be supported by many stakeholders, which must be made in accordance with the needs and interests of the involved people. So, it requires specialized policies which need to be addressed for the proper and standard way to create and propose the architecture. This issue is addressed and a solution is provided by [7].

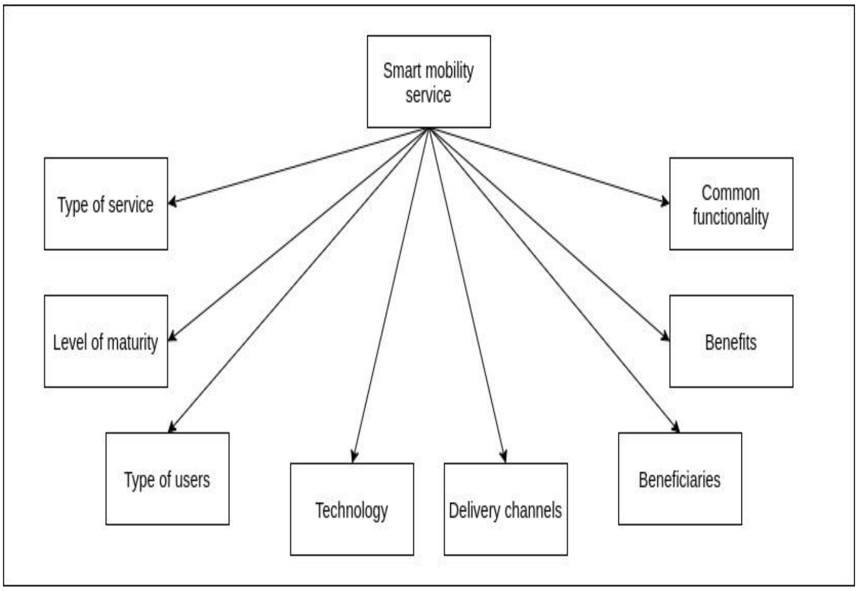

Fig. 5: Taxonomy for planning and designing smart mobility services

The author evaluated 42 smart mobility services and projects to find out the existing solutions for the good practices which can be implemented in further projects. However, the information is quite shallow and unstructured for which the author proposed a solution as shown in Figure 5. This solution provides a common theme to discuss and share information about such services. The taxonomy consists of eight dimensions: type of service, level of maturity, types of users, technology, delivery channels, beneficiaries, benefits, and common functionality. The eight dimensions mentioned by the author in the paper provide a proper base to start work with smart mobility services in further projects. This will further help to be a standard for smart mobility services in the future.

F. A Smart Walker for the Frail Visually Impaired

Smart technologies have brought different beneficial innovations in real life. One of these innovations is helping differently-abled people in their daily life. In [8], the authors have proposed an architecture as shown in Figure 6. The device is mounted on a walker or trolly for people who are weak and cannot walk by themselves and are visually impaired.

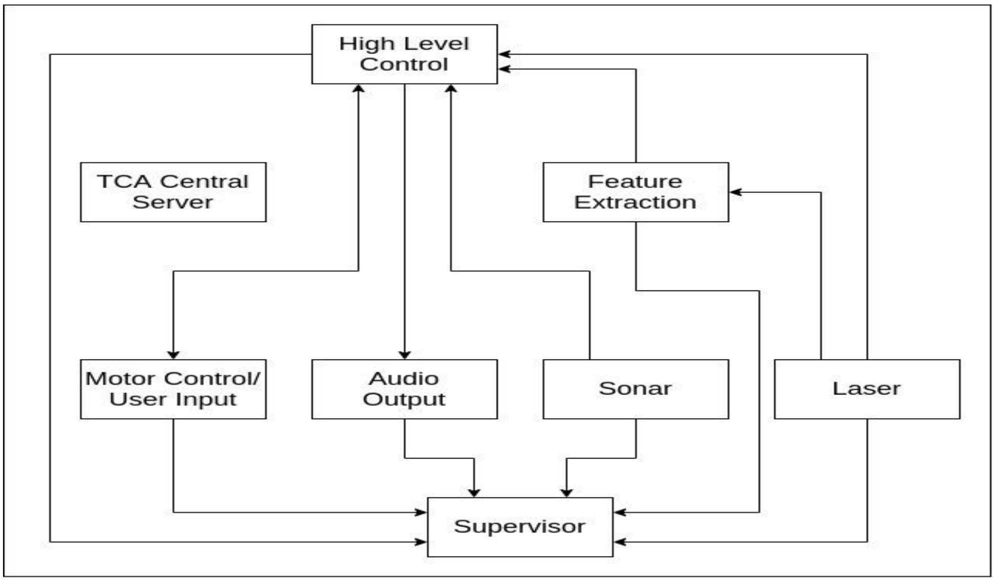

Fig. 6: Software Architecture for Personal Adaptive Mobility Aid

The device is called PAM-AID(Personal Adaptive Mobility Aid). The device will use different sensors to monitor the environment and aid the users while walking. This device has two types of modes in which one of them will give them suggestions from the environment and another will assist even with the mobility of the user by navigating safely around obstacles. The rating provided by the users was compiled using 5 point Likert scale and the overall usefulness of the device was found to be 3.8. So, the device is still in the pilot phase and will take a little more time for the device to be implemented. The knowledge from the device can be used in further for proposing the architecture.

G. A multi-layered blockchain framework for smart mobility data markets

Smart mobility services contain different devices connected to a network which feeds data to the central server which can be analyzed for further processing and making business decisions. As the data are central someone who has access to the central server easily changes the data and makes the system inefficient. So, instead of using central authority like traditional methods, we can use modern decentralized techniques to store data. Also, due to security, and privacy, many systems are not yet implemented in the network. So, in this problem blockchain comes in handy.

The blockchain network is basically a public ledger in which the data stored can be coined as transactions which can be only validated if the nodes in the network will validate the data. So, blockchain technology can be used in smart technology systems to make the network secure and private. In [9], the author has proposed the use of blockchain technology in smart mobility data markets. The block diagram for the blockchain network is shown in Figure 7.

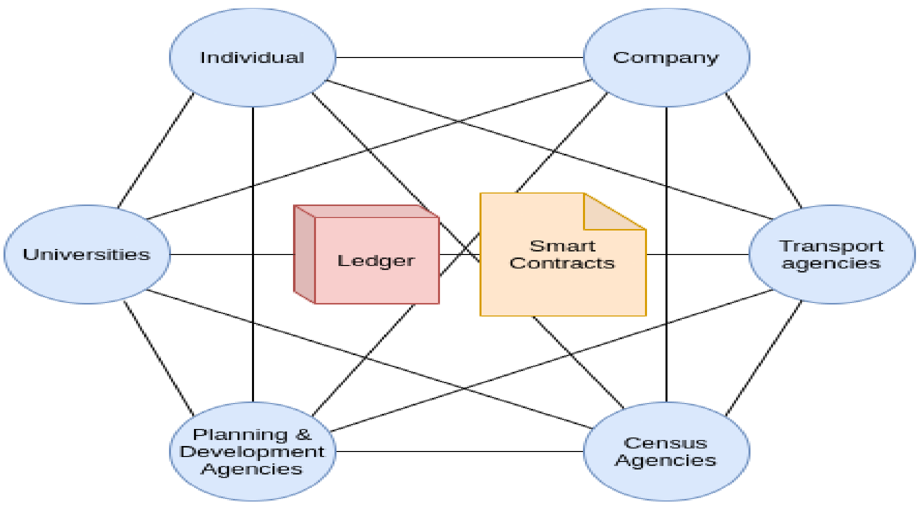

Fig. 7: Blockchain network architecture

Blockchain technology redefines the meaning of trust and can be used more securely than traditional networks. Blockchain networks will also be used to provide incentives to the people who are in the network and provide data. So, the benefits of blockchain technology can be summarized as the decentralized trust mechanisms and the incentives for the data providers. These benefits will be helpful for both the consumers and the vendors by keeping their data private and secure. But, the drawback of a blockchain network is that if more than 51% of the nodes are turned out to be dishonest then the network fails, and another is a large amount of energy consumption, the estimated energy consumption of Bitcoin is 100MW[9]. However, energy consumption is also provided with incentives.

The nodes in the blockchain network as shown in Figure 7, are the participant of the blockchain network. The network is not owned by a single entity whereas it is collectively owned by all the nodes in the network. So, there is very less chance of turning the nodes into dishonest nodes. The data collected by different devices in the vehicles, sensors, card readers, etc. are calculated and fed into the blockchain network with a smart contract. A smart contract is a contract which will be invoked automatically when certain criteria are met, so in the case of the data, it can be invoked when someone tries to access the data and if the payment is made, the data is automatically made visible without the need of third-party. So, using these kinds of technology is beneficial in a large network of interconnected devices which do not have a single authority and need secure and private communication.

IV. EVALUATION & DISCUSSION

The architecture and technologies from [1]-[9] have provided different architectures and applications of smart mobility services and some provided evaluation techniques. The comparison of the architectures and summary is shown in Table I.

Reference	**Evaluation**	
	Architecture	***Summary***
[4]	This paper shows a map-based platform which collects data with the geographical coordinates.	The architecture proposed in this system is a pool of devices that is in a network which collects data for further analysis.
[5]	A parking management system architecture for better parking in cities.	The vehicles and the parking stations contain devices that are connected to a network which will notify if there are available spaces for parking.
[6]	VSN architecture comprises the social network and IoVs working together for anomaly detection.	The social networks and IoVs are two different networks integrated with the help of a Vehicular social network that analyzes data from both networks and detects any kind of anomaly in the traffic.
[7]	Taxonomical architecture is not a hardware/software architecture but instead, it is a comprehensive architecture to provide standard planning and design for building smart mobility services.	This model contains eight dimensions which are used as a base criterion to develop any kind of smart mobility services in the future. This will help the researchers to provide a better and more easily understandable way to develop smart mobility services for everyone.
[8]	PAM-AID architecture contains sensors and devices that process real-time data and make decisions.	PAM-AID is an aiding device for frail and visually impaired persons. It contains a sonar sensor that detects any obstacles in the path and provide information to the user or moves accordingly as per the modes manual or auto respectively.
[9]	The blockchain technology used architecture with the IoT devices from different ecosystems.	Blockchain technology is used to store and retrieve data collected from the devices which will make the device more secure and private. In this way, one of the main problems regarding IoT which is security and privacy can be addressed.

Table 1: Evaluation of State of Art

From the evaluation of different architecture, we can identify that all the IoT ecosystem follows the same pattern of architecture as mentioned in Section II. So, to propose a new architecture we can use the benefits of the different architecture we have studied. The problems in the IoT ecosystem are the lack of security and privacy of the data as the main analysis is done with the help of real-time data to make business decisions. Also, another problem which is address not by many authors but is shown properly in [7], is that there is no standard to plan and design smart mobility services so, everyone's service has become different from one another. The criteria shown in [7], i.e. the eighth dimensions of planning and designing can be used in further research to propose an architecture which can be a powerful tool for further work. Also, the statistical evaluation done by [8], 5 points Likert Scale can also be used in our further evaluation to analyse the data and make an average out of it.

V. PROPOSED ARCHITECTURE

From the evaluation and discussion of different architecture and smart mobility services, we propose an overall architecture which is scalable, secure, private and can be used to integrate any kind of IoT devices for the foreseeable future. The diagram of the proposed architecture is shown in Figure 8.

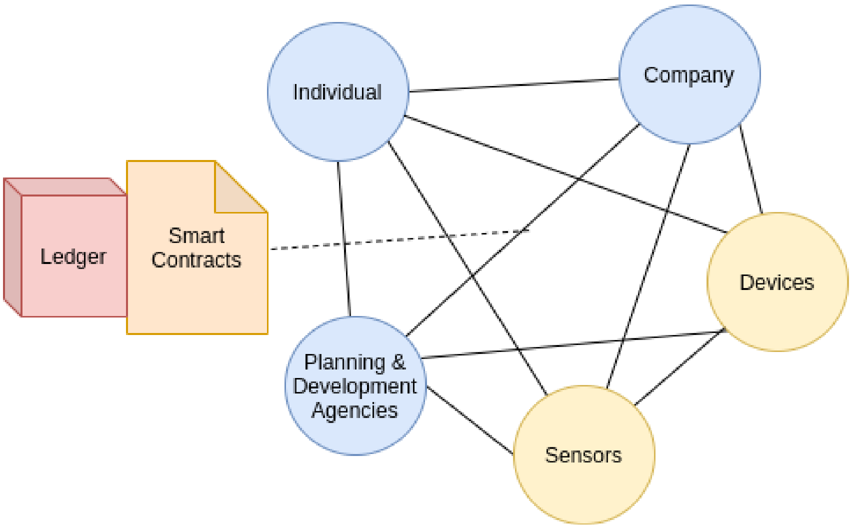

Fig. 8: Proposed Architecture for Smart Mobility Services

From [4]-[6], [8] we can see that there are different kinds of smart mobility services provided and yet we have experienced very little of those. It's because of the lack of trust and security reason that the devices are not implemented in the real life. So, using the benefits from [9], we can integrate the IoT devices in the blockchain network not only for the data markets but for information sharing, data acquisition, and IoT integration which will make the network more scalable. Also, from [7] we can say that the dimensions should be properly identified in the smart mobility services so the eight dimensions in the architecture as shown in Figure 8 are:

- Type of service: Parking, Planning, Traffic, etc.
- Level of maturity: Testing is going on and implementation is needed.
- Type of users: Every citizen of a nation, so that everyone will be beneficial
- Technology: Blockchain technology, IoT devices, etc.
- Delivery channels: Vehicle stations, Mobile app stores.
- Beneficiaries: Everyone on the network who provides valid data and the people who validate the data
- Benefits: Secure, private and trusted platform in a decentralized network with no single entity.
- Common functionality: The architecture can be implemented in any society and any device that want to be a part of this network can be a part of this network just to broaden the users.

The proposed architecture will be beneficial for normal people too because they can also gain incentives from the network by providing data.

VI. CONCLUSION & FUTURE WORK

The research is conducted on different smart mobility services to propose a common architecture which is proposed in this paper. Architecture can be used in society to make smart mobility services more reachable and more prominent. These kinds of services are implemented to make society better and the data which are collected from these systems can be used to further enhance transportation mechanisms and lessen the faults occurring on daily basis.

The limitations we faced during our research were:

- Lack of information regarding IoT services in developing countries
- The testing of blockchain network requires a large amount of manpower which was difficult to find.

With the limitation addressed here we suggest that this research can be further conducted in the following fields:

- The research can be used as a base for the introduction of blockchain technology in public for the decentralized trust mechanisms.
- The information gathered has been considered only for the devices but with a survey among users the IoT ecosystem will be more efficient.

ACKNOWLEDGEMENT

This paper is the result of the project Smart City, supported by Dr Rabindra Bista, Kathmandu University.

REFERENCES

[1.] Khan, R. et al., "Future Internet: The Internet of Things Architecture, Possible Applications and Key Challenges," in *Proceedings of the 10th International Conference on Frontiers of Information Technology*. IEEE, Dec. 2012.

[2.] R. Mangiaracina, A. Perego, G. Salvadori and A. Tumino, "A comprehensive view of intelligent transport systems for urban smart mobility", *International Journal of Logistics Research and Applications*, vol. 20, no. 1, pp. 39-52, 2016. Available: 10.1080/13675567.2016.1241220 [Accessed 21 May 2020].

[3.] Marchetta et al. S2-move: Smart and social move. In Global Information Infrastructure and Networking Symposium (GIIS), 2012, pages 1–6. IEEE, 2012.

[4.] P. Marchetta, E. Natale, A. Pescape, A. Salvi and S. Santini, "A Map-Based Platform for Smart Mobility Services", 2020. [Online]. Available: http://wpage.unina.it/pescape/doc/1570102215.pdf. [Accessed: 21- May- 2020].

[5.] R. Barone, G. Tesoriere, T. Giuffrè, M. Morgano and S. Siniscalchi, "Architecture for parking management in smart cities", *IET Intelligent Transport Systems*, vol. 8, no. 5, pp. 445-452, 2014. Available: 10.1049/iet-its.2013.0045 [Accessed 21 May 2020].
[6.] Z. Ning, F. Xia, N. Ullah, X. Kong and X. Hu, "Vehicular Social Networks: Enabling Smart Mobility", *IEEE Communications Magazine*, vol. 55, no. 5, pp. 16-55, 2017. Available: 10.1109/mcom.2017.1600263 [Accessed 21 May 2020].
[7.] G. Cledou, E. Estevez and L. Soares Barbosa, "A taxonomy for planning and designing smart mobility services", *Government Information Quarterly*, vol. 35, no. 1, pp. 61-76, 2018. Available: 10.1016/j.giq.2017.11.008 [Accessed 21 May 2020].
[8.] S. MacNamara and G. Lacey, "A smart walker for the frail visually impaired", *Proceedings 2000 ICRA. Millennium Conference. IEEE International Conference on Robotics and Automation. Symposia Proceedings (Cat. No.00CH37065)*, vol. 2. Available: 10.1109/robot.2000.844786 [Accessed 21 May 2020].
[9.] D. López and B. Farooq, "A multi-layered blockchain framework for smart mobility data-markets", *Transportation Research Part C: Emerging Technologies*, vol. 111, pp. 588-615, 2020. Available: 10.1016/j.trc.2020.01.002 [Accessed 21 May 2020].