

# Survey of Internet of Things and Smart Cities: The New Age of Cities in Big Data and the Innovation and Challenges

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December 15, 2023

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COMP 5118 - Trends in Big Data Management

## 1 Abstract

Internet of Things is a relatively new innovation, and can help expand and create Smart Cities, and bringing us into a new age of cities. Though we do face problems and challenges with big data and its sustainability, efficiency, and magnitude of the complexity and many sectors and technologies involved. Many research papers have proposed solutions and architecture examples to tackle these issues and push forward Smart Cities and working with Internet of Things. A taxonomy is presented which covers many of the approaches and as well describing them in detail and categorizing them into their classifications. With the classifications, we can then analyse the solutions and approaches covered and hope that the taxonomy used and the summarization of the research papers used, to be an overall comprehensive review of the current work and help to give a preview and look to the new developments and issues and solutions occurring [19]. The survey will compare and contrast many of the approaches and will aim to give great insights and identify any gaps and give future work that may be needed.

## 2 Introduction

Throughout the world and in the major cities such as Shanghai, Seoul, New York City, London and other big cities, are transforming and turning into "Smart Cities" [22]. These smart cities enable cities to become much more effective and efficient, and turn communities into safer places, give more economic opportunities, and as well better quality of life. The cities are undergoing a new evolution which involves the use of wide spread technology, which will come and affect every part of the city ecosystem and connect and communicate all devices to provide instant decision making powered by artificial intelligence and computer vision, and provides the city to grow, connect, and making lives much better through the technology [23]. Smart city with internet of things allows for everything to be connected and have communication between devices and connect software and hardware. Internet of things covers devices that have sensors, software, and physical networks that are embedded systems, to ensure connection and communication of big data with multiple and various other devices that are connected through the internet

[25]. This is important as it allows every appliance, technology, and device to have quick and fast communication to ensure efficiency, more features to be added, cost saving, and allowing for cloud computing, artificial intelligence, and machine learning to be used [25].

Internet of Things in Smart Cities as discussed and mentioned, cover a lot of different topics, fields, and aspects varying from the services provided, infrastructure and security. With the fast emerging innovations of Internet of Things and it being implemented in cities to develop smart cities, there is an overwhelming amount of new technologies, models, methods and opportunities that will upgrade the way cities work and run. By having the ability to look and examine at many different leading papers in the industry which introduce major research contributions towards Internet of Things in Smart Cities, we will be able to look at the progress and new findings in this area. With all the devices that are connected and constantly communicating, there is a overwhelming amount of data collection and it being processed.

This survey paper will aim at covering the Internet of Things in Smart Cities structure and architecture and the technologies it uses to address many of the challenges and data issues, that they are facing, and as well bringing up the solutions and contributions towards it and any research problems that are apparent and summarize them across the papers. Exploring the different areas of the smart cities and Internet of Things applications and the impact on the quality of life, urban communities, and the efficiency of systems is important to analyze the technologies and architectures. It is crucial to look at the technical and infrastructural challenges in Internet of Things in Smart Cities and the integration of the technologies in applications and as well adapting to the evolution. The implementation of Internet of Things is very complex and face a lot challenges such as security issues and in this survey, we will expand on the various applications and research being done recently and present a taxonomy which will cover many approaches in detail and applications and distinguish between them. These categories will feature the new innovations, problems faced and the approaches used to solve them and will compare and contrast and comparatively analyse them with a comprehensive summarization, that will give the outlook of Internet of Things in Cities. There are 4 classifications within the taxonomies which are: Architecture of Internet of Things, Artificial Intelligence and Machine Learning, Big Data and Data-Driven Applications, Environmental and Sustainable Efficient Methods,.

This topic is relevant as Internet of Things is becoming increasingly more popular and all the benefits it brings is great for city life and very interesting with all the new technologies and advancements and all the new possibilities that are available through this [25]. The methodology in this survey is to select the most relevant and recent papers that push forward and bring new contributions in this field and have unique solutions and explanations and architectures. The taxonomy covers a lot of the areas of interest in smart cities integration with Internet of Things and using comparison on the papers. The surveyed papers include the challenges and innovative ideas and are on the communities affected, security, and infrastructure and more. The papers were examined and put into categories to explain the papers and what they talk about. It is hard to talk about

Internet of Things and addresses the issues as there is too much volume and complexity overall and very challenging and difficult due to limitations currently in place such as too many factors and technology issues. The main components and parts of the approach and result obtained are the multiple parts of the Internet of Things in Smart Cities and having a system and structure that can identify the issues and give insights. It can be limited by the fast paced ecosystem and evolving Internet of Things and creation of new advancements.

The fundamental actions is the integration and connectivity of the systems and applications of the Internet of Things, and important for urban communities for efficient management, development, and safety protections. As of now, the Internet of Things systems for smart cities is by manual approaches, and with their being more systems and higher complexity and volume, the need for more automated systems is of the need. Having the systems be able of handling more data and complex applications and being more efficient is required and to tackle this, there needs to be a structure which will go on about the different issues and give insights for approach and solution, and will be flexible and give the architecture for the Internet of Things and with the classification providing analysis of the methods and the relevance to smart cities and the problems. With all the existing work in this context, the main goals is to survey the approaches and to present the taxonomy which will helpful to developers and to provide a comprehensive overview of the research and give solutions from the papers.

### **3 Background**

For this survey paper, the target audience are the developers, stakeholders, and people generally interested in the space of Internet of Things and also Smart Cities. The audience may include researchers, academics as well. The motivation behind this to conduct the survey, is to read and summarize the recent contributions in the field and organize them and give insights and to learn more and forward smart cities and Internet of Things. There is a lot of development in this field as Internet of Things(IoT) was getting developed in 1999, and involves systems communicating with each other across the internet and rapidly expanding and getting smart and better with all the new found focus on it and being involved in many technologies [11].

### **4 Methodology and Approach**

The methodology of this survey was to gather over 10 papers that were selected using some constraints and a criteria. It included being relevant towards Internet of Things and related to smart cities, and having new contributions and approaches that are unique. The papers selected were over a few different topics and involved looking for Artificial Intelligence and big data papers and also papers that deal with sustainability or services. Papers were selected to be fairly relevant, and from 2016 to present, with most being from this years and few remaining others from 2020-2023. The taxonomy that was built, allowed to categorize the papers into specific and distinct groupings and easier to dissect. Each category covers a decent portion of scope and represents an area of research. Sources were gathered from Google Search, Google Scholars, and IEEE Digital Library, which

allowed to give the vast amount of papers and research available to be selected. The authors of the papers are well respected and most of them are top of their respective fields and contributed meaningful knowledge. With the papers collected and given their taxonomies classifications, the papers are then summarized and analysed with a focus on identifying, comparing, and contrasting main points on the methods, findings, key points, the contributions made, and as well limitations of the studies themselves and against others. Main points and discussion follow the survey details and provide input on the surveyed body of work. The main idea and thesis and as well the synthesis of the paper is also given and providing the critical analysis of the results is given. As the main idea is to compare and contrast the trends and directions that the research contributions are heading in the field, it is important to narratively go through them and address the problems of the papers and other information.

## 5 Survey Details

In this section, we will go over the 4 different taxonomies and its structure, and summarize and categorize the major research contribution in their respective area. Insight and well in depth analysis will be given and highlight the main research directions in the field and also identify research problems and approaches and methods used. Trends and key findings will be shown and the relation between papers and with big data as well and showcasing important contributions, relationships, and themes, and integrating ideas and combing elements to form a comprehensive view. To show the importance of the taxonomy categories, we will summarize the main contents and the issues and the solutions of it and the importance of it.

### 5.1 Machine Learning and Artificial Intelligence in IoT

Machine Learning and Artificial Intelligence are big parts and important for Internet of Things and its integration within them and its involvement with application in smart environments. Artificial Intelligence and Machine Learning and as well Deep Learning are critical for Internet of Things for smart cities and can be used for many services [21]. For this section, 4 different papers will be used to give a view on the use of Machine Learning, Artificial Intelligence and the role it plays in smart cities and in IoT technologies and how they are important to be added and can create highly advanced and effective Internet of Things systems. Artificial Intelligence and Machine Learning can be used to take advantage of Big Data and Internet of Things in Smart Cities to make predictions and correlations from data in cities [10]. Various amounts of Machine Learning algorithms that are classified into 4 algorithms, which are: Bayes Network, Naive Bayesian, J48, and Nearest Neighbour algorithms are used for the correlation of effects of weather data and using the algorithms, have gave them the ability to realize that Internet of Things applications in Smart Cities could leverage these algorithms to become more efficient and effective [10]. This paper is able to extend the understanding of the services used by using Machine Learning and effectively use Big Data and large number of samples to predict from the data sets and use methods that can analyse the samples. The paper was able to contribute by highlighting the Machine Learning algorithms and concepts to make data-driven decisions and have services run on it and handle large data. There was also a lot of potential and use for other technologies and services for smart cities with Machine Learning, Big Data [18]. As mentioned, big data is continuously growing at an

exponential unprecedented rate and can cause a lot of issues, with everyone sending and receiving data and makes it challenging to store and handle the data and to communicate between devices [18]. The cities require to operate on big data and as well for the technologies and Internet of Things and by using devices which are powered by IoT and Artificial Intelligence, and are extracting data from the devices to use Internet of Things in multitude of services such as healthcare, education, and transportation, which contains big data as well [18]. For all the heavy requirements for complex services and systems, Artificial Intelligence is used and new built architecture and models, to have the framework. The model used to handle Big Data and Internet of Things Smart Cities is a four layer tiers of architecture to analyse the systems for the cities and help plan, with a top tier and bottom tier and 2 tiers [18]. The issues they tackled were the huge amount of data and with their model they are able to handle it and have it processing in real time and can then affect traffic and plate recognition instantaneously [18]. This allows them to make decisions for applications in Smart Cities using Artificial Intelligence and processing the data and having innovative contributions by having data efficiently processed and can cover many applications and is very scalable. This adds to the growing field of AI and in IoT as it can show how they are important and can process data and be used in urban communities. Deep learning as well is evolving and helps grow Internet of Things by using its features and methods for many services and systems and help to have overall better quality of life for all residents in cities that are using smart technologies [21]. Artificial intelligence and with deep learning, implemented on Internet of Things allow for this to occur and with every object connected and communicating, it allows for unique network connection addresses and can be used to exploit the data and use it for whatever appropriate [21]. This gives the ability to have a lot of data and information collected and stored and then with artificial intelligence to make decisions on the data and can then be used for various services for smart cities [21]. As you can see with all the trends of Artificial Intelligence and Deep Learning, it allows for data to be used more efficiently and then can be used effectively for all the data and highlights the need for AI to be more widespread and in Internet of Things applications to save money, energy, and allow for areas such as transportation to have the vehicles movements tracked in real time and can make traffic and lights more efficient [21]. For example, a 5 layer architecture can be used and can cover the main points and effectively manage them and with deep learning to evaluate data and make analysis on data and then give decisions which are the most effective as possible [21]. This can overcome the challenges of the large scale of data incoming, and protects privacy concerns as well. Smart Cities can as well be utilized by Internet of Things to ensure great communication between important technology devices, and can then enable to have great analysis, and have a implementation framework which is iterations of interviews and discussions and can integrate with smart environment developments [9]. It can include getting data, making predictions, controlling systems, and tracking and monitoring analytics, and can be used in smart environments, cities, and make them ultimately more affordable, provide real time data, and tackle significant barriers and relationships that can be analysed with the framework [9]. As you can see with all the incoming new information, it shows that combining AI, ML, DL, and IoT, with Smart Cities is a very innovative way to have city services that can be scalable, customizable, and efficient. Architectures with many tiers and levels are great ways to use for data processing and also making smart decisions and gives importance to AI, which can handle the data and analyse them and can give frameworks to develop prediction models. With the trend of using more AI and deep learning models, the complexity issue

of data, can be solved much easier and services in the city from all ranges and appliances and devices are affected positively and can create a great way to make the smart city features and applications much more effective and strengthen to its best abilities. There is still much more ways to go in this field, as there are obviously security risks, data protection and spread of data, and the overall sustainability and scalability of the devices and algorithms.

## 5.2 Infrastructure and Architectures of IoT Systems

In this section, we will focus on the infrastructure and architectures of the systems of Internet of Things. They play a vital part, as they form the basis and foundation of the systems and are important to ensure effectiveness, efficient and tackle the main problems such as big data issues. They look at the development and designs of the systems and create the infrastructure necessary for the Internet of Things systems to work for their needs in Smart Cities. Smart cities need strong architectures, as with many more devices using Internet of Things, the risk of security issues are increasing tenfold, and with them creating a great number of data volume that is being used to process and send and other capabilities, analytic network process is needed to evaluate the smart cities and meets the requirements to work in complexity, which is needed [4]. Use cases can be used to control the sector and capabilities of technology out there, and can then be analyzed and evaluated to provide many applications and algorithms to support the ever growing population and the devices and having selection of the smart city and evaluating them properly [4]. Developing the Smart Cities also requires to deal with large amounts of homogeneous and heterogeneous systems, which are data which are the same type and systems that use many different types of devices, respectively [7]. Designing new architectures to ensure communications and the steadiness of it is important to upkeep, as all the services used in the smart city will rely on it, and having an approach of recovering the network and the services, when systems can fail, and being done automatically by the system is imperative [3]. Improving and innovating the existing infrastructure in the Internet of Things is important and having the architecture having multiple layers of IoT features that can then focus on different aspects of the smart city and support it [3]. These solutions can allow services to be connected and help the people in the city with cloud computing and keeping the services up and taken advantage of the scalability and cloud [3]. Architecture to handle the heterogeneous data sources are also being built and can handle the data classification, representation of information and management and unification of data [6]. The architecture can handle large tasks and give methods for challenges. The data streams have the data structured and have client server system [6]. Methods that can understand the applications of IoT technologies, can work on network technology and analyze smart city's construction process and show results that can take advantage of information and of technologies [8]. Internet of Things devices can give new advanced applications and communications and need a lot of devices and with needing to place sensing devices in cities can be hard, expensive, a framework such as IoTaaS can be utilized to have Internet of Things devices be available in urban communities using drones [12]. These devices can give an analysis of the economy of the smart city and the framework has many features such as users being able to have their features and device meet the needs of their wants, handle placement algorithms, and can monitor services and can scale to the needs and performance required to work effectively [12]. This makes it very important as it can track many services and resources and tackle the main chal-

lenges and give very available devices to be used and can help the infrastructure and meet requirements and is easily customize by users and makes it a very strong solution towards data, cost and up-scaling. Internet of Things also requires the smart cities community functions and services to be efficient, and with technologies and great architectures, this can improve. Use cases and applications, such as healthcare, safety, energy management, all are important and need to have reliable and strong infrastructures, to evolve the city life and handle the problems of security, limitations of technology and being efficient, and solve them by having project management and innovation that is efficient [15]. The papers all give great insight into what infrastructure and architectures are evolving into for Internet of Things systems for Smart Cities, with focus on developing network infrastructures that can support many Internet of Things devices in cities, and tackle large data, efficiency and the flow of data. The frameworks provide a way to have scalability and sustainability of systems and application across the city services to be running and have great security and energy efficiency. A lot of new ways that smart cities can go with how the technologies are going and developing, and have a greater focus on sustainability and features for the IoT systems and applications. Though you can find that there is more of a widespread and large systems of infrastructures that are all wildly different and unique, and hard to have one or few architectures that can address all the issues of scalability and more for IoT systems. They do give the foundation as stated and are crucial for infrastructures that are sustainable.

### **5.3 Big Data and Data-Driven Applications:**

The development of data-driven Internet of Things application are important as they have big data, artificial intelligence, machine learning, and services and many applications involved and affected in smart cities. As big data is growing a lot, systems for IoT need to be founded on big data systems, which can be various types of smart services and objects, and how they can make the cities turn into smart cities and bring them into a new age of cities [18]. Data analysis is done with the IoT sensors which gather data and using networks, you can recognize correlation of data and trends, and further analyse them and create models of the city from the IoT applications, by processing and analyzing the big data and can turn it into smart data, to make the city much more efficient and smarter [18]. Data can also be collected through complex frameworks after iterations and then analysing them to seek the potential of certain opportunities and keep cost and high usage down, and have the operations be much more intuitive [9]. The IoT systems and devices using big data, can improve the services and features of the smart city by improving data collection, processing and also analysing all the massive amounts of data and keeping up with the high scale of volume. Many methods and approaches are given to have it be real-time data processing and work with the big data scales and be applicable to various applications. As many more research is conducted, the approaches towards big data and data driven applications will improve, but will it ever exceed the ever growing and uncontrolled big data and mass amount of data out there in a city. With all the advancements in recent years and the ones highlighted, Internet of Things devices can access and use the big amounts of data that they produce from the different services and usage, and using the analytics of the smart city, they can then use the insights and information to make city life better by making the management improved. The IoT system in smart cities and big data are very related and can make each self better and improved and with new technologies, this will only get better.

## 5.4 Environmental, Sustainable, and Efficient IoT Systems

Efficiency and sustainable systems for IoT in smart cities are very much important, as every city looks to improve in environmental and sustainable aspects and as it improves all the quality of life ways of the city and its services such as transportation. It is good to have efficient energy management for the cities, as the demand for the energy is increasing and same for the IoT devices [24]. This can be tackled by offering solutions of extending lifetime for devices that have low power and energy harvesting in cities [24]. This means implementing case studies for the smart cities and having scheduling optimization and cloud based approaches to have more energy efficient cities and a management framework [24]. Traffic systems can have a lot of data and also very expensive [1] and with transportation systems being very crucial to daily life, cities use IoT to optimize efficiency of the services [13]. The research contributes by having smarter transportation systems by having efficient models to have safer and effective roads and traffic systems. Traffic and pollution affects the city in many ways and is not sustainable and not very environmentally friendly, and by having solutions that will consider speed, traffic types and real time data including pollution and evaluating data at certain times, it allows the data to be effective to improve traffic and make smart cities more organized and viable to live [14]. Addressing these issues and getting the main contributions of the having solutions to improve energy efficiency for IoT systems and reduce power being used and the data footprint, can be very effective and change the level of a city and smart city, ultimately. It can improve on resource management and make it much smarter and optimize data and make communities and cities more sustainable and environmentally friendly. From the papers, more work is being done increasing the research and methods used and focusing on having more sustainable Internet of Things systems and devices and make it truly a smart city. It can still improve on scalability as challenges across the board are still faced and also improve the problems of efficiency and effectiveness which may be sacrificed, but in all, great progress being made towards IoT systems and devices being more sustainable for long term city goals.

## 6 Analysis/Discussion

With all the stated information and overall summarization of the various papers and its respective taxonomies that represent certain aspects of the Internet of Things in Smart Cities, it should give a total comprehensive view of all the new advancements, research, methods, solutions, and mainly the architectures that were presented to tackle and solve the issues and problems that can plague this field. Seeing how the IoT systems can work with Artificial Intelligence, Machine Learning, Big Data and Data Driven applications and provide efficient and sustainable environmental system, it can give great insights and identify the main themes and trends to seek and any gaps that are missing to have future work on. Working with AI and ML, has allowed the data processing to be faster and be better and work with many applications and services. Though there are still lingering data privacy issues and still a long ways to go in this field and rapid new innovations coming out every year. Data-Driven systems make the services and systems more efficient and give real time data, though it is still difficult to handle very large and complex big data sources. Smart cities have also become more efficient, sustainable, and more Eco-friendly through the efforts of energy efficiency and networks and models that emphasize sustainability, and can grow much larger to address the environment effects.



The architecture and infrastructure that's been introduced such as the drones, which can extend the use of IoT devices has helped shape the smart cities and provide more scalability and efficiency. With all the new research coming in, the evolution of Internet of Things and Smart Cities keeps on expanding and getting better with increasing efficiency and effectiveness of decisions being made by the systems. More unified solutions should be the emphasis to address major issues like volume of data or security, especially for devices in the same smart city. More of the systems are becoming more flexible and more user friendly and giving the user the power to control with their architecture of the Internet of Things devices, and much better than fixed architecture. These taxonomies that were created can have more research and development done and can improve across all the metrics.

## 7 Conclusion

Internet of Things is a very powerful tool and has many applications and uses across the industries of smart cities and can help to elevate the statuses and impact of services provided to make the quality of life in the smart city much higher. In this survey paper, many approaches, solution, and infrastructures were provided in great detail to cover and address the main issues that each aspect of the field it faces. Four different taxonomies were introduced that gave in-depth and insightful details, summarization and the body of work in the major researches happening in the areas of concern for smart cities and Internet of Things. The taxonomy covers much of the topic in interest in details and contains recent and top papers and contributions and research of well respected authors, which can effectively categorized and comparatively analyse the approaches and implementations that were done [19]. The taxonomy should ultimately provide a comprehensive review and summary of the recent contributions and provide the needed insight for that distinct area and should be useful for developers, researchers, academics, and people interested in the field of smart cities and involvement of Internet of Things. Future work could be done to give attention to the rising scalability of data, and security issues. More work towards the complexity of the systems and having more standardization papers and research can be done. There are a few out there right now and can be increasing in the near future and important to make it easier across all devices to not have unique scenarios and implementations for solutions [5]. It gives way to future work and the overall growing potential of Internet of Things and evolution of Smart Cities and how they can become much more efficient and sustainable with the approaches and solutions given towards the problems encountered.

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