Impact of IoT (Internet of Things) in Smart Cities

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Abstract: Smart cities have matured and increased in potential in recent decades. Realistically, the IoT has opened up new opportunities, establishing a collection of important enabling technologies for smart cities and making it feasible to develop and automate certain services and applications for the city's many stakeholders. This study presents a literature analysis on IoT-enabled intelligent cities to highlight the significant trends and unresolved difficulties of integrating IoT technology to construct sustainable and prosperousintelligent cities. The paper provides a review of the essential technologies proposed for IoT framework implementation by analysing the well-known smart city approaches and frameworks by employing a classification that is split into eight domains. It is an expansion over the conventional classification that is used in the majority of similar works.

Keywords: Framework, Technical, Sustainable, Development

Introduction

IoTtechnologies are crucial enabler in the current bright city environment, taking the smart city concept to the big data scale. Based on technological studies conducted by Ericson, the company predicts that "29 billion devices will be linked by 2022"[1]. Statista Research predicted in “2019 that there will be 75 billion connected IoT devices by 2025” [2], with an associated annual economic impact of "USD 11 trillion by 2025" [3]. These results demonstrate that the IoT will be a game-changing technology, providing new opportunities and challenges for developing smartservices and applications. The rise of "smart cities," in which IoT is a crucial enabler of more efficient innovation and environmentally friendly growth, is directly tied to the importance of the IoT. A smart city is the combination of human actors (many stakeholders and users, such as citizens, city operators, administrative institutions, public and private companies, and so on) and technological infrastructures(e.g., "city sensors and actuators used in many domains, such as mobility and transportation, environment, energy, healthcare, governance, industry 4.0, and so on; smart home and intelligent buildings devices; and personal devices, such as smartwatches”). This complexity is mirrored in the extensive range of methodologies, settings, fields of application, and technological solutions available for developing and managing smart cities. Smart cities may improve with the help of installed and integrated IoT systems by gaining new capabilities and features with drastically less human involvement [3].

In addition, it is of the utmost importance to conduct research on the social problems that are solved and the benefits to society that are accrued as a result of the implementation of such technologies, such as the manner in which they may contribute to the "Sustainable Development Goals" set forth by the United Nations as a component of the 2030 Agenda [5]. Supporting many data sources, traversing different protocols and data formats, assuring interoperability and scalability, and making component sharing more straightforward are all major technical concerns for IoT-enabled intelligent cities today. This is critical for reducing overhead and boosting the city's sustainability since it will eliminate the need for several data entry, storage, and analysis systems.

In the work, we combine IoT and smart city solutions by categorising them into the following eight categories: government, housing, transportation, commerce, industry, the environment, and health care.

IoTTechnologies its Architecture

With the advent and expansion of IoT, a dramatic change in how digital devices share information and interact with one another and the physical world [1]. Integrated into IoT designs are data sensing and actuation from and to devices, message transmission and receipt, data storage, processing, and analysis, and data exploitation through cloud computing, fog computing, and edge computing, as well as services and applications. Many different types of technology are used in the development of IoT frameworks and number of approaches for building large-scale functional architectures based on OSI has been proposed. Some studies [1,6] characterise a typical IoT design as having three layers: perception/sensing, network, and application. Publications [7-12] expand on the idea above by breaking it into five distinct architectural layers: a perceiving/sensing layer, a transport/network layer, a processing/middleware layer, an application layer, and a business layer. Figure 1 depicts a 3-layer and 5-layer IoT infrastructure.

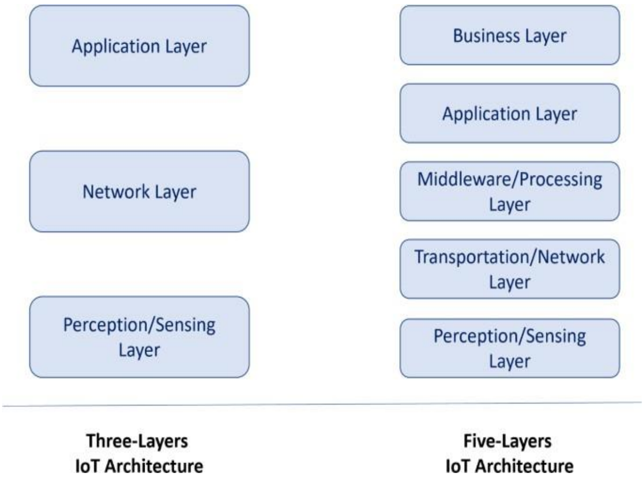

Figure1. Three- and five-layer IoT designs were the most prevalent in the literature.

PerceptionLayer

The perceptual layer, also known as the sensing layer, is connected to the physical layer. This layer consists of a network of sensors and actuators that are able to communicate with one another and the outside environment through wireless networks[8].

NetworkLayer

The networking layer handles everything to do with sending and receiving data. Network gateways/brokers may act as go-betweens when connecting disparate IoT nodes, allowing for data transmission and reception between various sensors for "machine-to-machine communication".The data may be sent using several ways and protocols. Technologies such as Bluetooth tag communication and near-field communication are two examples of proximity communication methods.Networks with a broader service area often use wireless technologies, including “Wi-Fi, Zigbee, LoRaWAN, Sigfox, and 5G. Bluetooth and Bluetooth Low Energy [16], two low-power wireless communication protocols for LANs,”[16] are unrivalled at transferring low-bandwidth data between mobile devices within 10 metres. They connect technological devices in intelligent environments.

Middleware/ProcessingLayer

The processing layer, or middleware, serves several functions. Considering that data may be collected from various sources using various methodologies that were not necessarily meant to communicate and interact with one another, it may serve as a data aggregator module, for instance. The middleware layer must do the required programming and model abstractions to enable interoperability between linked devices. Multiple layers of interoperability must be ensured.

Communication that is efficient from beginning to finish among "devices, brokers, servers", etc. must be attained and protected on a technical level [30]; on a semantic level [31], Big Data technologies like "XML, RDF, OWL Ontology, and linked data (L.D.)" are used to provide consistent data representation in addition to semantic data augmentation, which will lead to an increase in the system's expressiveness [32].

The ApplicationLayer

In the application layer, users may access the chosen software and services. As indicated in the previous section on the network layer, message protocol management is often implemented based on a three-layer IoT architecture.

Because of the proliferation of IoTdevices and systems, event-driven applications[43] have become more popular (exploiting push protocols). Since the first generation of smart city systems prioritised vertical applications and was generally constructed using extract[42], transform[42], "load/extract" [42], "load (ETL/ELT)" [42]this is a fundamental shift in paradigm since processes and languages, which traditionally only allow pull protocols, do not generally enable push protocols . However, event-driven IoT applications are constructed and implemented with the help of several ecosystems and frameworks [32]. Based on the nodeengine, Node-RED [33] allows users to build application flows in a visual environment by combining nodes or blocks.

The BusinessLayer

The business layer is an organisational layer that is designed to organise all of the back-end and front-end tools that use the data from the application layer to provide high-level big data analytics and visualisation services. This layer is located above the application layer in the three-layer architecture.This was accomplished by developing the business layer. These services include the development of business models, the improvement of decision-making procedures, and the execution of what-if analyses. This may be achieved using cutting-edge, interactive visual analytics tools [35] and predictive models built using machine learning, deep learning, and A.I. techniques [34]. The business layer also includes all the processes carried out by the system administrator to assess, regulate, and keep the platform or framework running smoothly.

IoTsecurity issues need their separate topic. The "General Data Protection Regulation (GDPR)" standard [36] requires strict adherence to and compliance with all of these requirements.

IoT-Enabled Smart City Components

The study of IoT deployments in smart city environments constitutes a significant body of work. The articles that were published between 2010 and 2021 on the subject of "smart city" which is a large number of resources that need to be exhaustively and systematically reviewed.Figure 2 shows the chronological development of these works to provide a sense of the expanding interest in these topics (grouped by publication year). Note that the part count for 2021 may explain the apparent fall in the number of published articles during the last year.

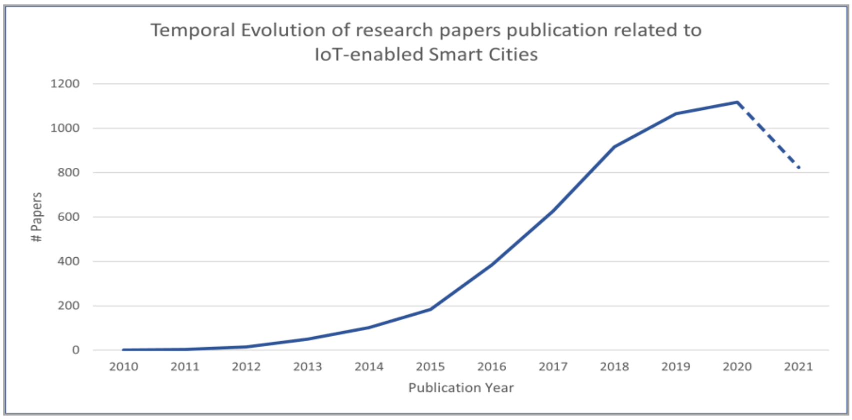

Figure2. The chronological progression of research publications on IoT-enabled smart cities as obtained from the WoS database.

In spite of this, several categorisation strategies are offered in the research published to date for smart city frameworks [36] and solutions [36] in a wide variety of application sectors [36]. For this reason, we based our investigation on prior assessments and surveys. As a result, the literature review was conducted according to the following standards:WoS looked for evaluations and surveys having "smart city" and "IoT" in the title, abstract, or keywords.

Books and articles published between 2018 and 2021 were selected for this assessment because they were the most relevant to the topic.

The findings reported here are based on surveys and assessments of fifty IoT-enabled smart cities that satisfied the criteria outlined earlier. One of the goals of this article is to present an overview of the IoTandthesmart cities that is broader or more in-depth than the one provided by the 50 surveys that were analysed. We also found that the few general surveys returned did not adequately address the connections between the various smart city domains (and their associated sub-domains and scenarios) and the IoT technology used in each case.
Eight categories, including "governance, living and infrastructures, mobility and transportation,economy, industry and production, energy, environment, and healthcare" [42], are generally used to categoriseintelligent city components and application areas (see Figure 3). These eight domains were established to provide the most comprehensive description of the broad environment we uncovered. The six-domain taxonomy presented in [1,37] is expanded upon in this technique. Not only is this taxonomy not meant to be all-inclusive, but there may be instances when the categories listed below are not strictly orthogonal due to their potential to be used interchangeably in different settings.

Figure3. Classification of smart city domains, the corresponding parts, and the application fields.

SmartGovernance

Incorporating ICTs (information and communication technologies) into government is what we call "smart governance." Incorporating information and communication technologies, or ICT, into city governance practises has the potential to improve collaboration between Government institutions, municipal authorities, commercial firms, and individuals collaborate to simplify bureaucratic procedures and make faster, more informed choices. Unique municipal services, specialised channels, and network integration are all feasible means to this end. Citizens may participate as "users as sensors" by using their smartphones to collect data of interest to intelligent communities. This is an example of the mobile crowdsourcing paradigm [40].

IoT technologies are linking local, state, and federal governments with their constituents and the private sector, therefore changing traditional municipal governance transactions and procedures into intelligent government resources [41,42].

SmartLivingandInfrastructures

Managing and bettering public services—such as those in the cultural, touristic, and educational spheres—that contribute to residents' overall quality of life is part of the intelligent living domain, as is the expansion of smart city infrastructures (such as smart homes, intelligent buildings, etc.) IoT enables the rapid deployment of a wide range of smart building features, including climate control, stormwater management, security systems for managing validated building access, surveillance cameras and human activity tracking [55], alerts for fire incidents and gas leaks, structural stability monitoring tools [56], etc. The living and infrastructure sector usesmanyIoT technologies, each best suited to a specific use case or situation. When the IoTis combined with Building Information Modeling (BIM) technology, a very accurate digital twin of the physical structure may be created [57]. "Smart homes" are settings in which “sensors, actuators, and personal devices are connected through wireless networks and often directed by A.I.”[58].

Services for Smart People to Use in Their Everyday Lives: IoTgadgets have several uses that improve the lives of their owners in many ways. In order to better manage and serve tourist stakeholders, one cultural activity is "intelligent tourism management," which makes use of mobile apps, GIS/location-aware services, audiovisual feeds, AR/VR, and social media [64]. This data may be used to improve sustainability, tourist experiences, and destination competitiveness [65].

Trends, challenges, and future directions

More and more instances show that IoT smart city applications and technology are rapidly proliferating. However, as we have seen in the previous sections, there are still a lot of open questions that may be answered in the future; thus, this integration process is not yet complete.

Interoperability issues arise because many smart city apps were developed independently, in vertical silos [3,18]. This means that each app has its own unique approach to data collection, storage, and analysis. Repairing incompatibilities may lead to productivity and financial gains. As a matter of fact, enabling backward compatibility through the exploitation of earlier systems and gradual deployment and integration is a direct outcome of boosting the interoperability of devices, applications, and services [19]. However, event-driven and push protocols [32] have been implemented because to the IoT/IoE paradigm's widespread adoption, making it possible to not only observe the city and construct event-driven apps. Literature offers few remedies. only apply to specific domains, thereby only addressing the specific problem at hand and never allowing for any software reuse [3]. Modern IoT-based systems for smart cities [41,42] have gradually embraced the microservice-oriented architecture paradigm to manage the multiplicity of IoT devices and applications. This facilitates the deployment and expansion of standard service-oriented architectures [32]. “IoT-based systems must be scalable for accurate data analysis and real-time or near-real-time processing” [55]. These considerations are particularly important for catastrophe risk management [56] and resilience planning, two fields where community participation is essential, since they allow for the development of more powerful tools capable of conducting real-time analysis and simulations.

Smart city platforms are expanding toward inter-institutional IoT applications and infrastructure. This allows for the development enormous, enterprise-supporting infrastructures with enhanced scalability and decreased infrastructure costs because of their shared nature across numerous operators [36]. Possible developments include the widespread adoption and implementation of cutting-edge network technologies like 5G [28,59]. Innovations in network and device solutions are crucial. Adoption of cutting-edge network technologies like 5G and improved efficiency in construction processes and technologies might lead to net zero carbon emission building solutions [45]. Increased communication between intelligent devices and all stakeholders in “a smart city and the development” of more smart services for “a better quality of life” are made possible by revolutionary computing paradigms like deep learning[66] and artificial intelligence (A.I.) solutions [66], semantic technologies, and natural language processing (NLP)[66].\.

We analysed every application area and issue based on their relevance to the Sustainable Development Goals to better understand the social concerns IoT and smart city technologies may help tackle.To do this, we shall provide a high-level overview of the 17 SDG indicators: no poverty [45], no hunger [45], health and happiness [45], excellent education [45], and equal rights for men and women [45]. Self-sustaining towns and communities[45]; access to clean water and sanitation; reliable and inexpensive electricity; good jobs and economic development; a thriving business sector; cutting-edge technologies; a smaller gap between the haves and have-nots; sustainable consumption and production; climate action; marine life; terrestrial life; justice, peace, and effective institutions[45].

Following is a list of SDGs that we found to be linked to the IoTandsmart city application domains based on our literature review:

- Zero Hunger: Good Health and Happiness: Smart healthcare solutions [45] enhance the effectiveness of healthcare given in hospitals, facilities, and at home. Smart agricultural [7] solutions increase access to essential "resources, such as food, and allow precision agriculture" [25]. When it comes to tracking critical events and circumstances in healthcare [50], such as the COVID-19 pandemic, extensive data collection and analysis may be quite helpful;
- Quality Education: The convergence of online and in-person education is enhanced by the use of intelligent education systems [66];
- CleanWaterandSanitation:In order to manage wastewater treatment [33] and lower water use [69], "smart water" technologies are put into place. When it comes to the construction and maintenance of reliable water supply systems, this is an essential consideration;
- AffordableandCleanEnergy:Better power distribution and use [46] is made possible by intelligent energy solutions and energy grids [3,58], which in turn helps reduce power consumption [54] and opens the door to the exploration of fresh;
- EconomicGrowth and DecentWork:Because of the significant push toward smart

and digital public administrations [39], intelligent governance solutions [37,42] contribute to economic development [42]. People, companies, and intelligent city actors may all benefit from reconsidering the flexibility of employment and labour [44] and defining the economic value associated with them thanks to smart economy solutions [28];

- Industry, Innovation and Infrastructure: Smart technical frameworks for efficient production in the industrial sector (88) and the information economy are being developed thanks to intelligent industry solutions [3,14,33];
- Communities and Sustainable Cities:Several features of the IoT-enabled smart city help to make smart city neighbourhoods more eco-friendly. For instance, smart transportation solutions [3,66] encourage smart transportation and IoT(IoT) paradigms to produce near-zero emissions and decrease traffic flows. As a result of these elements, living in smart cities will improve significantly [45];
- Climate Action: The assessment and regulation of air quality and the usage of fossil fuels, in addition to the environmental impact of these factors in terms of "CO2, NO, NO2, etc." (significant fossil impacts combustion), are aided by smart environment technologies [3,66] that monitor air quality and pollutant levels [66]. Stable governments are characterised by peace and justice. Smart approaches to government [3,38,39,46-54], which encourages broader and more thoughtful citizen participation, leading to more public good consensus and enhanced equity [45].

Conclusions

The purpose of this research is to conduct a literature assessment on the present status of the architecture for smart cities that make use of the IoT. This research prompted the need to understand and classify current trends in deploying IoT technology as a critical enabler for smart cities' efficient and sustainable evolution. One of the goals was to pinpoint the most critical problems that would require fixing along the road. The research included the architecture of essential IoTtechnologies and classifying smart city ideas and frameworks into eight distinct application domains. According to this report, the integration of IoT solutions and smart city frameworks has become more complex and all-encompassing in recent years, surpassing the previous generation of vertical silo applications focused on smaller areas. Vertical silos emerge when data are collected and "siloed" in a single system that is unavailable to the IoT. Open Messaging Interface, an open API standard, and Open Data Format are E.U. IoTprogrammes. Players and stakeholders may communicate procedures, data, and results on more platforms. Future intelligent applications will need to manage and optimise increasingly complicated heterogeneous information, data, systems, sensors, and other devices. Growing number of stakeholders and actors actively engaging in smart city environment as consumers of services and providers of unique content may also be crucial.

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