

A Comprehensive Survey on Internet of Things for Smart Cities : Applications, Communication Protocols, Network Types and Requirements

Azmera Chandu Naik¹, Lalit Kumar Awasthi², Priyanka³, T. P. Sharma⁴

¹CVR College of Engineering, Hyderabad, Telangana, India

²National Institute of Technology, Uttarakhand, India

³National Institute of Technology, Hamirpur, Himachal Pradesh, India

⁴National Institute of Technology, Hamirpur, Himachal Pradesh, India

¹azmerachandunaik2@gmail.com, ²lalitdec@gmail.com, ³dr.priyanka@nith.ac.in, ⁴teek@nith.ac.in

Abstract— Rapid population growth in recent decades has made it imperative to find innovative answers to pressing problems in areas like transportation, healthcare, energy, and public works. One of the most interesting technology enablers for meeting these difficulties is the Internet of Things (IoT), which involves the global interconnection of a vast quantity of items equipped with electronics, software, sensors, and network connections. The IoT is a cutting-edge contemporary technology that has the potential to link a wide variety of digital objects to the web, enabling a wide variety of new services within the context of a "smart city". These gadgets come equipped with a wide range of sensing, acting, and processing options. Attractive IoT technology and big data analytics are making smart city plans a reality all around the world. By improving infrastructure and transportation networks, decreasing traffic congestion, managing trash, and enhancing the quality of human life, these services are revolutionizing urban areas. When fully implemented, the IoT will allow for the seamless integration of a wide range of disparate end systems and the open sharing of data for the development of an abundance of digital services. The focus of this essay is on an urban IoT framework, a still-broad category that is yet to be characterized by its particular application domain. Actually, urban IoTs are made to support the Smart municipal concept, which seeks to apply current communication technology to supply extra services to municipal administration and people. This article, therefore, offers a comprehensive analysis of the relevant technologies, protocols, and architecture.

Keywords- Cloud Computing, IoT, Network architecture, Network Connectivity, Smart Cities, Smart Infrastructure, Urban development.

I. INTRODUCTION

Internet technology emerged in the 1990s, the word "IoT" (Internet of Things) first emerged in papers in 1999 [1]. The IoT is an interoperable network of computers, sensors, and other devices that allows cutting-edge services by connecting physical and digital items [2]. Numerous studies have analyzed cloud computing [4] and IoT-induced networks [3]. In contrast to many other services, the key drivers of IoT are Internet-based technologies [5-6] rather than customer requests or applications. The IoT makes it potential for objects to "communicate" through the use of embedded technology, sensor networks, and pervasive and ubiquitous computing [7]. In fact, the Internet of Things is crucial for modernizing many "dumb" forms of communication into "smart" ones [8]. The fast advancement of cloud technology has increased the efficiency of data storage and processing, decreased the cost of manufacture and deployment, and led to a dramatic rise in the usage of sensors in recent decades.

The IoT is an innovative communication paradigm that aims to connect a vast number of digital things to the web in a way that is both seamless and inventive. Its goal is to broaden and deepen users' experiences online [9, 10]. The emerging IoT sector is rapidly picking up steam as operators, suppliers,

manufacturers, and enterprises become increasingly aware of the opportunities it brings. The IoT is a cutting-edge communication strategy that envisions a future in which everyday objects are embedded with microcontrollers, digital transceivers, and appropriate protocol stacks, allowing them to communicate with humans and thus become an integral part of the Internet [11-15]. Therefore, the goal of the IoT concept is to further the Internet's pervasiveness and depth. In addition, a wide range of equipment, including as household appliances, security cameras, tracking devices with actuators and sensors, and automobiles, may be easily interacted with. Home automation, factory automation, medicine, mobile healthcare, elderly care, energy management, smart grids, transportation, and many more sectors have found uses for this idea [16]. With such a wide range of potential uses, however, it might be challenging to identify adequate solutions. As a result of this difficulty, a number of potentially competing strategies for bringing IoT systems into the real world have arisen. The implementation of an IoT network, including all of the supporting network services and devices, is still in its infancy, and as a result, there is no widely accepted standard approach. Not only are there technological challenges to implementing the IoT paradigm, but there is also a lack of a clear and widely

accepted economic model that may attract finance to do so [17].

Smart cities are a driving force behind new innovation in business, government, and academia. A city is deemed "smart" when investments in human and social capital, as well as traditional and modern forms of communication infrastructure, lead to long-term economic growth, a good quality of life, and responsible resource management through citizen participation in governance. To tap into the city's collective intelligence, a smart city must also integrate its information and communication technology (ICT), social and economic networks, and physical infrastructure. Smart cities often employ cutting-edge ICT and upgraded infrastructure to achieve their goals. The IoT in particular plays an important role in joining objects to the Internet and achieving numerous protocols for information transformation and connectivity [10–15]. There is a lot of investigation into the IoT's potential in the areas of sensing and autonomous control, communication, and big data analytics. This facilitates the development of novel applications and integrated solutions from a variety of academic disciplines that may be used to build a more sustainable society. By linking the physical and digital worlds through the interconnection of enormous numbers of electronic devices spread in homes, vehicles, streets, and other public areas, IoT-based smart cities may offer a variety of services for citizens and administrators. A few examples are smart parking lots, smart homes, smart energy grids, smart weather systems, smart traffic systems, and smart weather systems. As a result, there needs to be more study into the theory and practice of Internet of Things-based smart cities. Previous studies have classified IoT as either technology or application-based [8]. The benefits and drawbacks of using IoT-enabled technologies and protocols are extensively discussed in [10,12-15,18-23]. This area takes past data into account in real time using many sensory approaches [24]. Quality of service (QoS) in the network is a feature of IoT network architectures [25]. Similarly, IoT-based systems have used integration strategies to bring together disparate sensor setups [26], web servers [27], IoT platforms [28] for collecting data from the environment, and adaptable prioritization systems for scheduling [30]. These systems also use IPv6-enabled architecture [29], flexible IoT hierarchical architectural frameworks, and smart grid IoT systems to reduce power consumption. There has been much research into the proliferation of IoT applications [31]. Cyberville, digital city, electronic city, flexicity, information city, smart city, telicity, wired city, etc. are only a few examples of the many names given to modern towns that make use of the IoT [32]. Moreover, a variety of IoT-based apps have already been launched.

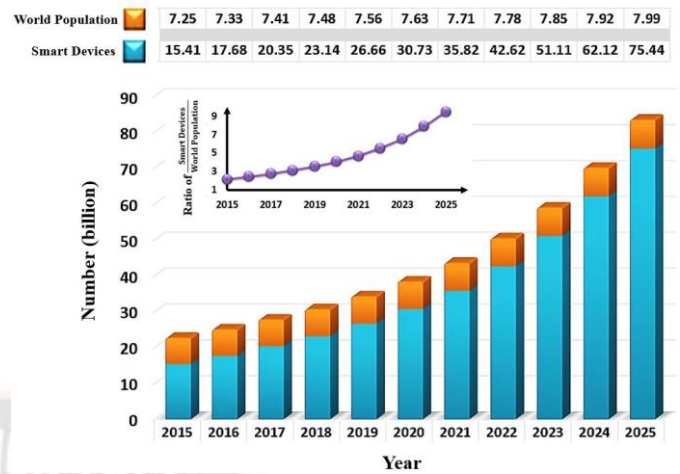


Figure 1. Population Vs smart devices connections

II. IOT-ENABLED SMART CITIES

The rise of IoT applications is largely attributable to smart cities. A smart city can be defined in many different ways, each of which depends on the individual using the term. A smart city is one that uses " the physical facilities, the information-technology facilities the social network, and the financial infrastructure needed to exploit the collaborative intelligence of the city " [33]. To provide enhanced public services and more efficient resource management, a "smart city" employs cutting-edge digital data collection and processing infrastructure. According to a UN report [31,34], by 2050, the world's urban population is expected to make up as much as 70% of the total. Major urban areas may account for as much as 80% of worldwide energy consumption and around 75% of global greenhouse gas emissions, but covering just about 3% of Earth's surface. As a result, modern cities face a host of issues. When considering the magnitude of the issues plaguing contemporary cities [35-37], sustainable growth and smart solutions are clearly a societal requirement. There has been a lot of study on the IoT and smart cities in the past several years. Numerous smart city and IoT platform applications have been documented throughout the past decade.



Figure 2. IoT Enabled Smart City

III. IOT APPLICATIONS IN SMART CITIES

There has been a lot of attention paid to the IoT in both academia and industry over the past decade. Crucial IoT characteristics can only be attained through human-to-human contact, which is made feasible through the use of specialized operating systems and communication protocols [38]. In Fig. 3, we see a high-level overview of the IoT in the context of many industries. Modern cities have benefited greatly from the development of ICT, which has made them both "smarter" and more productive. It is not necessary or even desirable to label every feature of smart cities as "smart." The adoption of the smart components depicted in Fig. 3 is intricately linked to the price and availability of the required technology.

A. Smart Mobility and Transportation :

Mobility in smart cities is typically exclusively associated with the transportation system. However, effective urban mobility may have other connotations. Intelligent transportation Systems(ITS), is primarily focused on the implementation of IoT networks to manage transport in terms of a number of capabilities and applications. Figure 4 depicts one application of a data parser in the context of smart parking in a smart city [39-40]. Smart software and smart mobility are hallmarks of innovative products and services. To be clear, the terms "smart mobility" and "smart transport" refer to the same services, most notably the application of Internet of Things networks to the improvement of individual mobility in smart cities. Pollution is a problem regardless of how you go around; that includes taking the bus, driving your own car to work, taking vacations, and any number of other activities. The goal of IoT-powered "smart" mobility and transportation systems is to make life in smart cities easier for people of all abilities (sensory and motor).

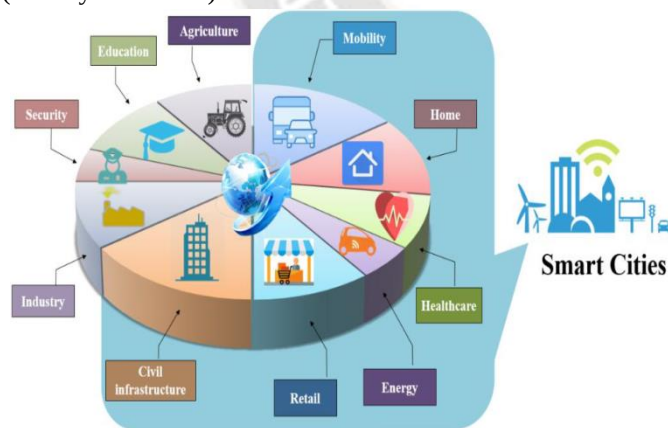


Figure 3. Smart cities - IoT applications

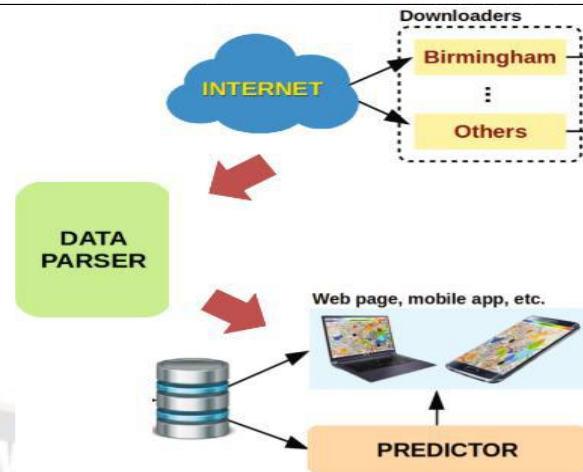


Figure 4. Data parser for smart parking



Figure 5. Smart E-bike monitoring system

Fig. 5 depicts a possible design for an electronic bike monitoring system. The smart parking service employs high-tech signage and road sensors to lead motorists to available parking spots across the city [41]. Fewer cars on the road means less pollution from cars, less congestion, and happier locals are all positive outcomes of this service. The smart parking service may be readily integrated into the urban IoT framework due to the abundance of European firms providing products for this purpose. In addition, RFID can be used to build an electronic verification system of parking permits in resident or disabled parking areas.

B. Smart Homes and Civil Infrastructure

Analysis of data gathered by wireless sensors might be crucial in bringing about the key parts of smart homes and civil infrastructure. One of its primary objectives is providing efficient management of the home's appliances and computer programs[43]. Fig. 6 shows a simplified diagram of an Internet of Things-enabled smart home. Sensors keep tabs on a number of factors, sending that information back to IoT hubs for further study. Using this data, homeowners can control their smart home's linked devices in real time and keep tabs on their smart home's environment and condition from anywhere. A

similar approach may be taken in the creation of smart civil infrastructure systems. The widespread use of sensors across civil infrastructure allows for continuous condition evaluation and, in certain cases, control of systems or devices. Many researchers are focusing on Internet of Things (IoT) developments for infrastructure right now [42, 43].

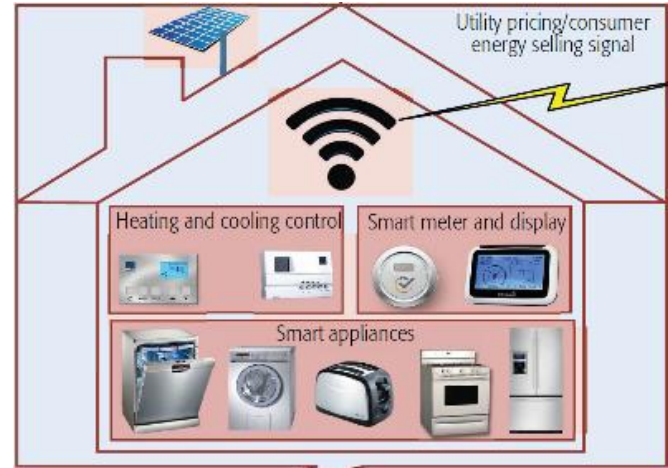


Figure 6. Illustration of IoT-induced smart home

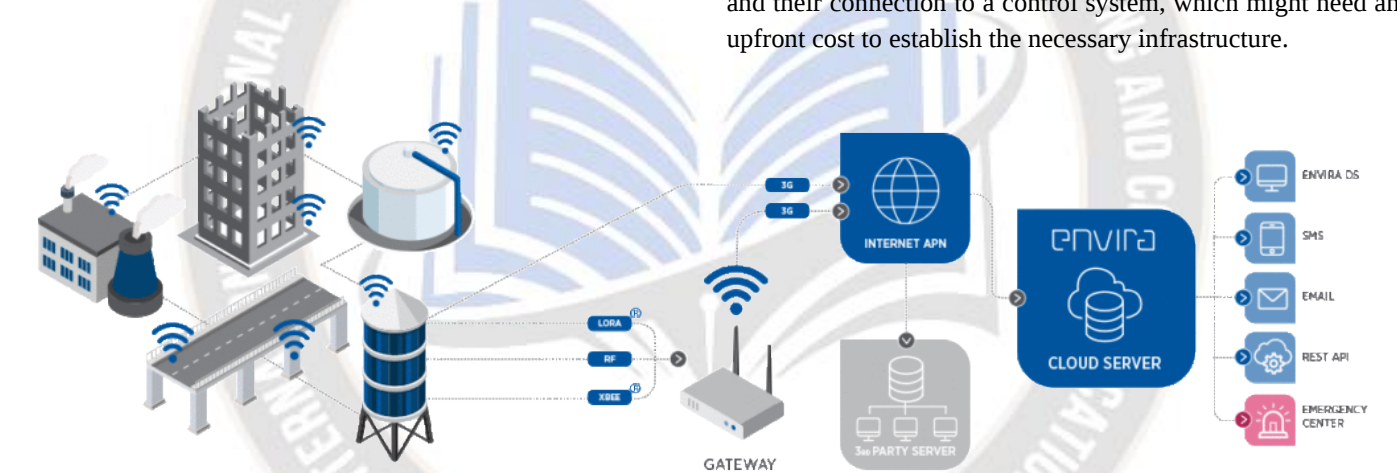


Figure 7. Structural Health of Buildings

D. Smart Lighting

Increasing the efficiency of the city's lighting system is crucial. For example, this feature may regulate the brightness of street lamps based on factors such as the time of day, the weather, and the amount of people in the area[43]. In order to function successfully, this service requires integration of street lighting with Smart City infrastructure. Taking advantage of the growing number of WiFi hotspots is also a realistic option. The streetlight controllers are a natural candidate for a failure detection system.

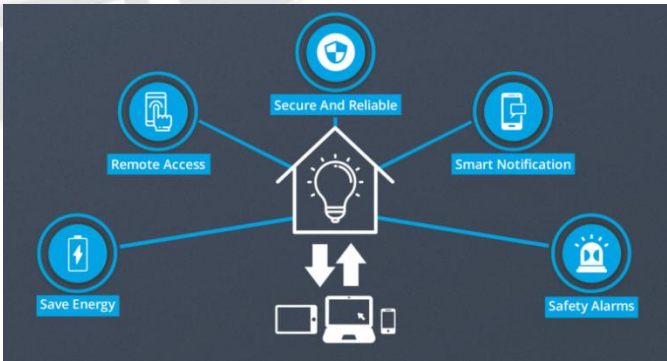


Figure 8. Smart Lighting solutions

E. Waste Management

Because of the high expense of the service and the issue of waste storage in landfills, waste management is a big concern

Regular assessments of each building's real state and identification of the regions that are most sensitive to outside effects are necessary for the proper upkeep of a city's historic assets. A database of structural integrity evaluations for buildings might be made possible by the urban IoT. For example, vibration and deformation sensors could be installed to measure the strain on a building, atmospheric agent sensors could track pollution levels, and humidity and temperature sensors could provide a comprehensive picture of the environment [44]. With this information at hand, repairs and upkeep may be laser-focused and preventative, cutting down on the need for costly, routine human inspections of the structure. Integrating seismic and vibration data will allow for better analysis and understanding of how mild earthquakes affect urban infrastructure for the first time. This database may be made available to the public as a way to demonstrate to residents the effort being put into preserving the city's heritage. However, the real fulfillment of this service requires the placement of sensors in the buildings and adjacent regions and their connection to a control system, which might need an upfront cost to establish the necessary infrastructure.

in modern towns. But a quick adoption of ICT solutions in this area might reduce costs significantly and have positive economic and environmental effects. Intelligent trash cans, which can measure the amount of trash inside and plot the most efficient route for garbage trucks, can help cut down on expenses while also raising recycling standards. In order to deliver such an intelligent waste management system, the IoT must connect the terminal devices.

F. Noise Monitoring

Like carbon monoxide (CO) in the air, noise may be thought of as an example of acoustic pollution. In this regard, the city council has adopted noise ordinances that apply during specific times in the downtown area. The quantity of noise being created at any one time in the areas where the service is utilized can be monitored by a noise checking service provided by an urban IoT. This type of service has several potential applications, including but not limited to the creation of a space-time map of the area's noise pollution and the enforcement of public safety via the installation of sound detection algorithms that can recognize noises like glass shattering or fighting.



Figure 9. smart waste management solution

G. Traffic Congestion

Urban IoT may be offering a Smart City service that takes into account traffic congestion in addition to monitoring air quality and noise levels. Camera-based traffic monitoring systems are already in use in many cities, but a low-power ubiquitous link might significantly improve data availability. The sensing capabilities and GPS installed in modern vehicles may be used in conjunction with air quality and sound sensors along a specific road to perform traffic monitoring.

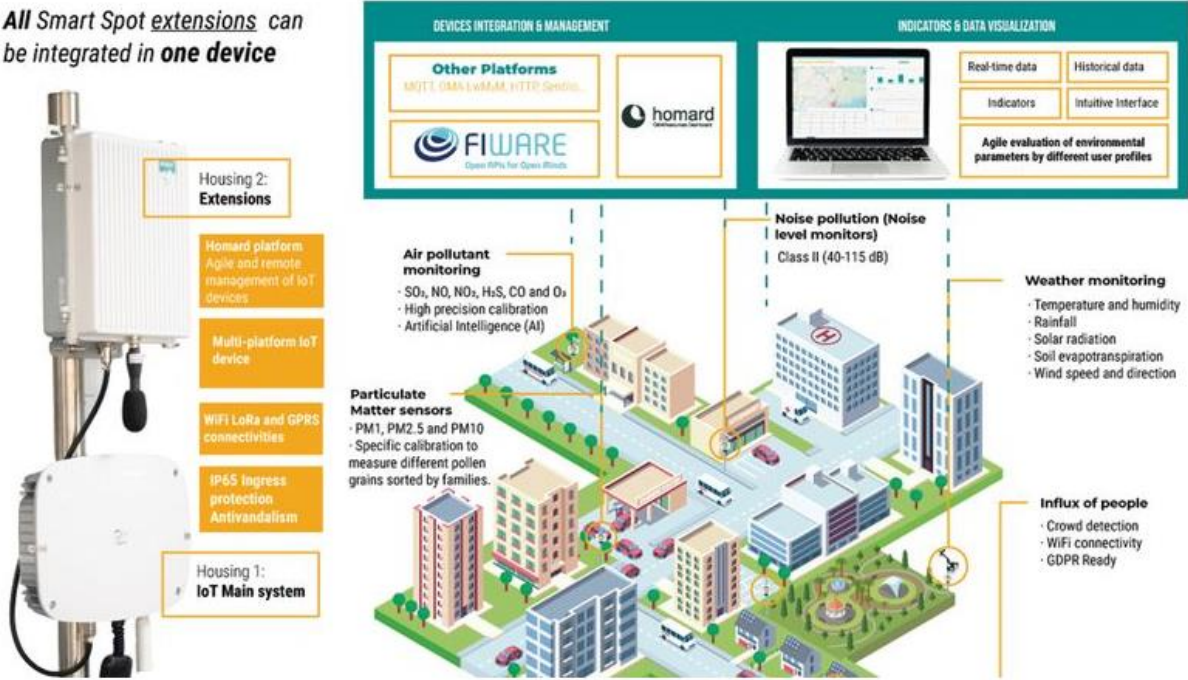


Figure 10. Noise Monitoring

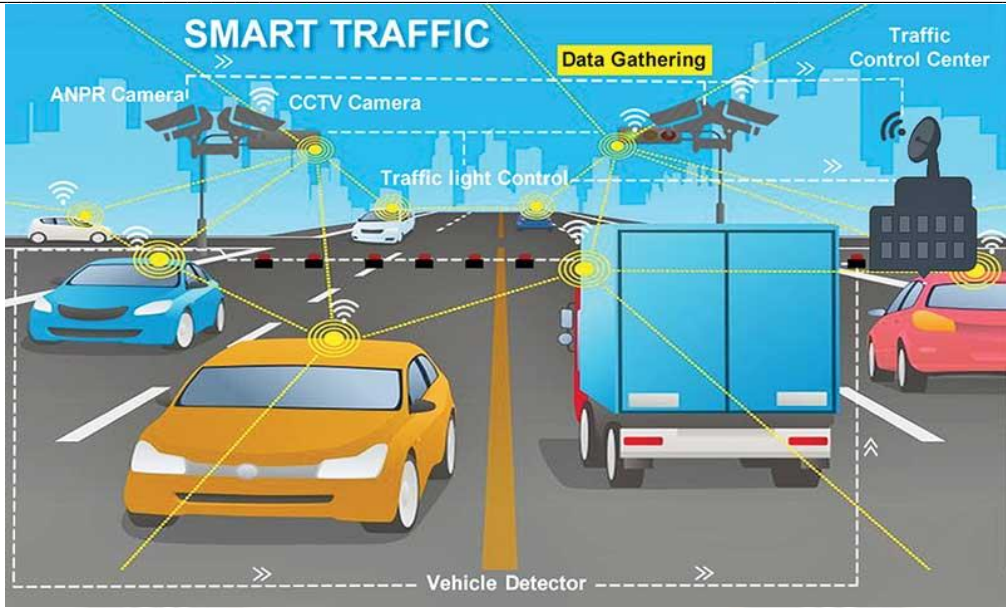


Figure 11. Smart Traffic

IV. COMMUNICATION PROTOCOLS & NETWORK TYPES

Several different types of communication protocols, both local and long-distance, are required for an IoT-based smart city to function properly. IEEE 802.11p, ZigBee, Bluetooth, Wi-Fi, WiMAX, and Wi-Fi are the most widely used short-range wireless technologies; they are often implemented in smart metering, e-healthcare, and vehicle communication [45–47]. In the field of intelligent transportation systems (ITS), long-range technologies, including vehicle-to-infrastructure (V2I) communication, mobile e-healthcare, the smart grid, and entertainment services are commonly deployed. GSM, GPRS, LTE, and LTE-Advanced are all examples of such systems. LTE-M is also seen as a step forward for C-IoT (cellular IoT). With Release 13 [48], the 3GPP aims to improve device complexity, battery life, and coverage. To further enable smart city applications, the LoRa Alliance is standardizing the LoRaWAN protocol in addition to well-known existing protocols, with a focus on ensuring interoperability across different operators. With its ultra-narrowband radio technology and all-encompassing star-based design, SIGFOX also offers a highly scalable global network for deploying low-power smart city applications. IoT-driven smart city applications require many network topologies to achieve desired levels of autonomy. IoT capillary networks deliver services over a localized region [49-50]. We may think of BANs, WPANs, and WLANs as some examples. Some examples of where this may be used include in street lighting, home automation, and indoor e-healthcare services. However, ITS, mobile e-healthcare, and waste management are only a few of the applications that make use of WANs, MANs, and mobile communication networks. Different information, size,

coverage, desired latency, and capacity define each of the aforementioned networks [45–47].

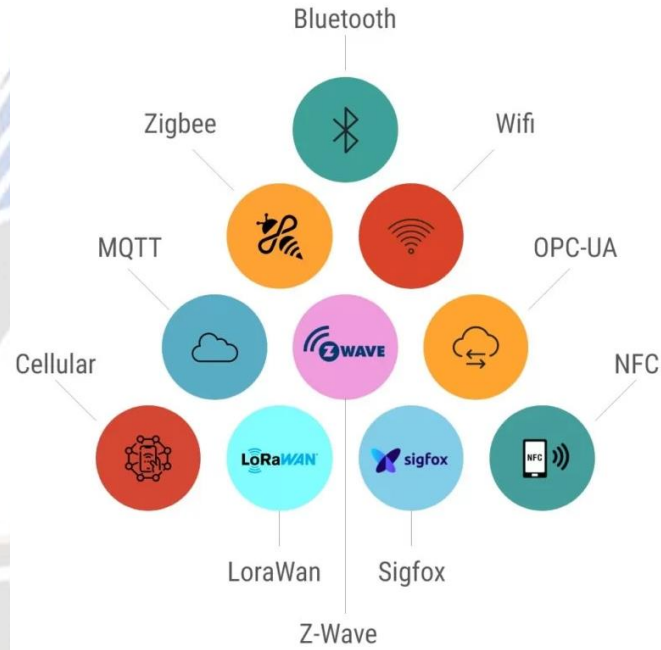


Figure 12. IoT Communication Protocols

V. OFFERED SERVICES & REQUIREMENTS

In the context of smart cities, the IoT provides a wealth of services that are invaluable for improving human life and leveraging local administration to cut costs. Some of the most important ones include smart lighting, garbage collection, and water supply. Installing smart IoT modules in grid stations, homes, and businesses can improve the efficiency of energy distribution and use. IoT devices in e-healthcare may be worn by patients to monitor vitals such as temperature, pulse rate,

and blood sugar level, allowing doctors to check in on patients more frequently. In addition, by keeping tabs on traffic flow with the use of WANs or GPS services in modern vehicles, urban IoTs can provide means to manage gridlock.

The IoT has several uses in a smart city, each with their own set of prerequisites. Ultra-dense deployments with improved privacy and security, as well as multivendor interoperability, are just a few of the expected benefits of solutions based on the IoT. To meet these demands, several novel approaches are required. It's possible, for instance, that traffic modeling is crucial for managing massive IoT traffic. By cooperating, IoT gadgets may send and receive manageable volumes of data. To do this, a gateway may be set up to work with any available means of communication. Data from IoT devices may be transmitted to a gateway via specialized short-range communications protocols like ZigBee, Bluetooth, Wi-Fi, and so on. Data aggregation may also be achieved through the use of femtocells, as well as LTE and LTE-A relays. Since aggregated traffic modelling can support a considerable number of nodes, it improves the performance of IoT networks. Since tiny IoT devices also require minimal power consumption to maximize device longevity, data aggregation may be used to provide minimum power dissipation through better coverage in addition to the network's capacity. Relays and intermediate gateways are used to enhance the channel conditions and achieve this goal. Overall, the security of every IoT device is a top priority. When numerous gadgets in a smart city are connected to the Internet, security becomes a major concern. HP found that in a smart city, nearly 70% of IoT devices have security issues such as weak encryption, lack authorization, and inadequate software security. Due of the vulnerabilities they expose, security and privacy are major problems.

VI. CONCLUSION

In this article, we have offered an introduction to the IoT with respect to smart cities, including its characteristics, needs, network topologies, and protocols for communication. Business players are already hard at work developing products that utilize the outlined technologies to deliver the needed applications, and standardization of these technologies is imminent. When compared to the sheer variety of possible IoT device layouts, the number of open and standardized protocols is surprisingly small. Furthermore, enabling technologies have matured to the point where they permit the real-world implementation of IoT goods and services, starting with field trials that should help dispel the uncertainty that has thus far impeded the general adoption of the IoT paradigm. The social impacts of IoT technology must be considered during the planning, design, and rollout phases. This article details the most recent advancements and trends in the idea of IoT-enabled smart cities.

REFERENCES

- [1] Ashton, K. (2009). That "Internet of Things" thing: In the real world, things matter more than ideas. *RFID Journal*. Available at: <http://www.rfidjournal.com/articles/view?4986>.
- [2] Guillemin, P., & Friess, P. (2009). Internet of Things strategic research roadmap. Cluster European Research Projects. Technical Report.
- [3] Vlacheas, P., Giaffreda, R., Stavroulaki, V., Kelaidonis, D., Foteinos, V., Poullos, G., Demestichas, P., Somov, A., Biswas, A.R. & Moessner, K. (2013). Enabling smart cities through a cognitive management framework for the Internet of Things. *IEEE Communications Magazine*. 51(6), 102-111.
- [4] Ballon, P., Glidden, J., Kranas, P., Menychtas, A., Ruston, S. & Van Der Graaf, S. (2011). Is there a need for a Cloud platform for European smart cities? *eChallenges e-2011 Conference Proceedings*.
- [5] Perera, C., Liu, C.H. & Jayawardena, S. (2014). The emerging Internet of Things market place from an industrial perspective: A survey. *IEEE Transactions on Emerging Topics in Computing*. 3(4), 585-598.
- [6] Perera, C., Zaslavsky, A., Christen, P. & Georgakopoulos, D. (2014). Context aware computing for the Internet of Things: A survey. *IEEE Communications Survey & Tutorials*. 16(1), 414-454.
- [7] Das S, Salehi H, Shi Y, Chakrabartty S, Burgueno R, Biswas S. (2017). Towards packet-less ultrasonic sensor networks for energy-harvesting structures. *Computer Communications*. 101, 94-105.
- [8] Al-Fuqaha, A., Guizani, M., Mohammadi, M., Aledhari, M., & Ayyash, M. (2015), Internet of Things: A survey on enabling technologies, protocols, and applications. *IEEE Communication Survey Tutorial*. 17(4) 2347-2376.
- [9] A. Zanella et al., "Internet of Things for Smart Cities," *IEEE Internet of Things J.*, vol. 1, no. 1, 2014, pp. 22-32
- [10] K. K. Vaigandla, "Communication Technologies and Challenges on 6G Networks for the Internet: Internet of Things (IoT) Based Analysis," *2022 2nd International Conference on Innovative Practices in Technology and Management (ICIPTM)*, 2022, pp. 27-31, doi: 10.1109/ICIPTM54933.2022.9753990.
- [11] L. Atzori, A. Iera, and G. Morabito, "The internet of things: A survey," *Comput. Netw.*, vol. 54, no. 15, pp. 2787-2805, 2010.
- [12] Dr.Nookala Venu, Dr.A.ArunKumar and Karthik Kumar Vaigandla. Review of Internet of Things (IoT) for Future Generation Wireless Communications. *International Journal for Modern Trends in Science and Technology* 2022, 8(03), pp. 01-08. <https://doi.org/10.46501/IJMTST0803001>
- [13] Karthik Kumar Vaigandla , Radha Krishna Karne , Allanki Sanyasi Rao, " A Study on IoT Technologies, Standards and Protocols", *IBM RD's Journal of Management & Research*, Volume 10, Issue 2, September 2021, Print ISSN : 2277-7830, Online ISSN: 2348- 5922, DOI: 10.17697/ibmrd/2021/v10i2/166798
- [14] KarthikKumar Vaigandla, Nilofar Azmi, RadhaKrishna Karne, "Investigation on Intrusion Detection Systems (IDSs) in IoT," *International Journal of Emerging Trends in Engineering*

- Research, Volume 10. No.3, March 2022, <https://doi.org/10.30534/ijeter/2022/041032022>
- [15] Dr.Nookala Venu, Dr.A.ArunKumar, Karthik Kumar Vaigandla, "Investigation on Internet of Things(IoT) : Technologies, Challenges and Applications in Healthcare," International Journal of Research, Volume XI, Issue II, February/2022, pp.143-153
- [16] P. Bellavista, G. Cardone, A. Corradi, and L. Foschini, "Convergence of MANET and WSN in IoT urban scenarios," IEEE Sens. J., vol. 13, no. 10, pp. 3558–3567, Oct. 2013.
- [17] A. Laya, V. I. Bratu, and J. Markendahl, "Who is investing in machine-to machine communications?" in Proc. 24th Eur. Reg. ITS Conf., Florence, Italy, Oct. 2013, pp. 20–23.
- [18] Botta, A., Donato, W., Persico, V. & Pescapé, A. (2016). Integration of Cloud computing and Internet of Things: A survey. Future Generation Computer Systems. 56, 684-700.
- [19] Atzori, L., Iera, A. & Morabito, G. (2010). The Internet of Things: A survey. Computer Networks. 54, 2778-2805.
- [20] Ahmed, E., Yaqoob, I., Gani, A., Imran, M. & Guizani, M. (2016). Internet of Things based smart environments: State of the art, taxonomy, and open research challenges. IEEE Wireless Communications. 23(5), 10-16.
- [21] Khodadadi, F., Dastjerdi, A.V. & Buyya, R. (2016). Internet of Things: An overview. arXiv:1703.06409.
- [22] Mattern, F. & Floerkemeier, C. (2010). From the Internet of Computers to the Internet of Things. Sachs, K., Petrov, I. and Guerrero, P. (Eds.): Buchmann Festschrift. LNCS 6462. 242-259.
- [23] Neirotti, P., Marco, A.D., Cagliano, A.C., Mangano, G. & Scorrano, F. (2014). Current trends in smart city initiatives: Some stylized facts. Cities. 38, 25-36.
- [24] Jalali, R. El-Khatib, K. & McGregor, C. (2015). Smart city architecture for community level services through the Internet of Things. IEEE 18th International Conference on Intelligence in Next Generation Networks.
- [25] Jin, J., Gubbi, J., Luo, T. & Palaniswami, M. (2012). Network architecture and QoS issues in the Internet of Things for a smart city. IEEE International Symposium on Communications and Information Technologies (ISCIT).
- [26] Rathore, M.M., Ahmad, A. Paul, A. & Rho, S. (2016). Urban planning and building smart cities based on the Internet of Things using big data analytics. Computer Networks. 101, 63-80.
- [27] Agrawal, P. & Chitranshi, G. (2016). Internet of Things for monitoring the environmental parameters. IEEE International Conference on Information Technology (InCITe).
- [28] Jayaraman, P.P., Yavari, A., Geogakopoulos, D., Morshed, A. & Zaslavsky, A. (2016). Internet of Things platform for smart farming: Experiences and lessons learnt. Sensors. 16, 1884. DOI:10.3390/s16111884.
- [29] Jung, M. Weidinger, J., Kastner, W. & Olivieri, A. (2013). Building automation and smart cities: An integration approach based on a service-oriented architecture. IEEE 27th International Conference on Advanced Information Networking and Applications Workshops.
- [30] Mardani, M.R., Mohebi, S. & Bobarshad, H. (2016). Robust uplink resource allocation in LTE networks with M2M devices as infrastructure of Internet of Things. 4th IEEE International Conference on Future Internet of Things and Cloud. <https://doi.org/10.1109/FiCloud.2016.34>.
- [31] Petrolo, R., Loscri, V., & Mitton, N. (2017). Towards a smart city based on Cloud of Things, a survey on the smart city vision and paradigms. IEEE Transactions on Emerging Telecommunications Technologies. 28, e2931. <https://doi.org/10.1002/ett.2931>.
- [32] Mohanty, S.P., Choppali, U., & Kougianos, E. (2016). Everything you wanted to know about smart cities: The Internet of Things is the backbone. IEEE Consumer Electronics Magazine. 16, 2162-2248.
- [33] Harrison, C., Eckman, B., Hamilton, R., Hartswick, P., Kalagnanam, J., Paraszczak, J., & Williams, P. (2010). Foundations for smarter cities. IEEE IBM Journal Research Development. 54(4), 1–16.
- [34] Vaigandla, K. K., Thatipamula, S. & Karne, R. K. (2022). Investigation on Unmanned Aerial Vehicle (UAV): An Overview. IRO Journal on Sustainable Wireless Systems, 4(3), 130-148. doi:10.36548/jsws.2022.3.001
- [35] Atzori, L., Iera, A. & Morabito, G. (2010). The Internet of Things: A survey. Computer Networks. 54, 2778-2805.
- [36] Baidura, N. & Ismail, B. (2016). Determining the Internet of Things (IoT) challenges on smart cities: A systematic literature review. Journal of Information Systems Research and Innovation. 10(3), 56-63.
- [37] Angelidou, M. (2014). Smart cities policies: A spatial approach. Cities. 41, s3-s11.
- [38] Khajenasiri, I., Estebsari, A., Verhelst, M. & Gielen, G. (2017). A review on Internet of Things solutions for intelligent energy control in buildings for smart city applications. Energy Procedia. 111, 770-779.
- [39] Stolfi, D.H., Alba, E. & Yao, X. (2017). Predicting car park occupancy rates in smart cities. Alba, E. et al. (Eds.) (2017). Smart Cities 2017. LNCS 10268, 107-117.
- [40] Sysoev, M., Kos, A. & Pogacnik, M. (2016). Smart driving: Influence of context and behavioral data on driving style. Galinina, O. et al. (Eds.). (2016). New 2AN/ruSMART. LNCS 9870, 141-151. https://doi.org/10.1007/978-3-319-46301-8_12.
- [41] S. Lee, D. Yoon, and A. Ghosh, "Intelligent parking lot application using wireless sensor networks," in Proc. Int. Symp. Collab. Technol. Syst., Chicago, May 19–23, 2008, pp. 48–57.
- [42] Qi, W., Ding, G., Xu, Y., Feng, S., Du, Z., Wang, J. and Long, K. (2014). Cognitive Internet of Things: A new paradigm beyond connection. IEEE Internet of Things, Journal. 1(2), 129–143.
- [43] Karthik Kumar Vaigandla, Shivakrishna Telu, Sandeep Manikyala, Bharath Kumar Polasa, Chelpuri Raju, "Smart And Safe Home Using Arduino," International Journal Of Innovative Research In Technology, Volume 8, Issue 7, 2021, pp.132-138
- [44] J. P. Lynch and J. L. Kenneth, "A summary review of wireless sensors and sensor networks for structural health monitoring," Shock and Vibration Digest, vol. 38, no. 2, pp. 91–130, 2006.
- [45] Karthik Kumar Vaigandla and Dr.N.Venu, "A Survey on Future Generation Wireless Communications - 5G : Multiple Access Techniques, Physical Layer Security, Beamforming

- Approach", Journal of Information and Computational Science, Volume 11 Issue 9, 2021, pp. 449-474.
- [46] Karthik Kumar Vaigandla, SandyaRani Bolla , RadhaKrishna Karne, "A Survey on Future Generation Wireless Communications-6G: Requirements, Technologies, Challenges and Applications", International Journal of Advanced Trends in Computer Science and Engineering, Volume 10, No.5, September - October 2021, pp.3067-3076, <https://doi.org/10.30534/ijatcse/2021/211052021>
- [47] Karthik Kumar Vaigandla, Nilofar Azmi, Podila Ramya, Radhakrishna Karne, "A Survey On Wireless Communications : 6g And 7g," International Journal Of Science, Technology & Management, Vol. 2 No. 6 (2021): November 2021, pp. 2018-2025. <https://doi.org/10.46729/ijstm.v2i6.379>
- [48] R. Ratasuk et al., "Narrowband LTE-M System for M2M Communication," IEEE VTC-Fall, 2014, pp. 1-5.
- [49] Radha Krishna Karne and Dr. T. K. Sreeja (2022), A Novel Approach for Dynamic Stable Clustering in VANET Using Deep Learning (LSTM) Model. IJEER 10(4), 1092-1098. DOI: 10.37391/IJEER.100454.
- [50] Karne, R. K. ., & Sreeja, T. K. . (2023). PMLC- Predictions of Mobility and Transmission in a Lane-Based Cluster VANET Validated on Machine Learning. International Journal on Recent and Innovation Trends in Computing and Communication, 11(5s), 477-483. <https://doi.org/10.17762/ijritcc.v11i5s.7109>.

