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RESEARCH ARTICLE

Review of Emerging Technologies for India's Sustainable Smart Cities

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ABSTRACT

Urban development and smart urban communities embody two ideal models of development that emerged in the previous century in response to cities' aspirations to be more responsive to the needs of their inhabitants, create conditions that promote a high quality of life, and foster sustainability in an increasingly globalized world. The recognition that excessive resource consumption brings humanity closer to a future where essential goods may become scarce for large segments of the population, coupled with significant technological advancements in resource conservation, urban monitoring, and informed decision-making, has brought these two disciplines closer than ever before, despite their distinct developmental paths thus far. Numerous initiatives aimed at building smart cities seek to harness information and communication technologies (ICTs) to enhance the effectiveness, efficiency, transparency, and accountability of communications and transactions between the government and citizens. Given the pivotal role of ICTs in the planning of smart cities, a considerable amount of city investment is dedicated to the development of new technologies. Consequently, smart cities create and

manage various innovative services that facilitate the dissemination of information pertaining to all aspects of citizens' lives through web-based and interactive applications. Smart cities possess several essential attributes: a smart economy, smart people, smart governance, smart mobility, smart environment, and smart living.

Keywords: Sustainable Smart Cities, Urban Development, Internet of Things (IoT), Big Data.

INTRODUCTION

Today, a wide array of sensors is being implemented worldwide to measure various variables both inside and outside of human-built homes. These sensors, coupled with actuators, are capable of performing complex tasks and are compatible with different platforms and contexts. The concept of smart cities has evolved to prioritize sustainability, citizen well-being, and economic development. The rapid urbanization and unplanned expansion of cities bring significant changes to economies at different levels—city, country, or region. Consider the consumption of water, fuel, and electricity, which leads to high levels of pollution, negatively impacting the lives of citizens, climate, and the environment. Cities have transformed into smart entities with the integration of various sensors, intelligent devices, energy meters, outlets, and appliances. This integration allows for unique and intelligent control over devices within homes. This paradigm shift brings sustainability and substantial savings, whether in terms of money or resources. While the ideal scenario envisions a web-based platform for processing information related to a single house in a fully-fledged smart city, achieving this nationwide is still a distant reality. To facilitate seamless operation, there is a need for standardized protocols across devices from different manufacturers. Such protocols would simplify device operation and reduce the need for advanced coding and time management skills.

Innovative concepts aid in identifying domain-specific technologies, protocols, and privacy data for IoT environments with specific purposes. Our research model addresses various issues related to smart home devices, including location determination and the provision of services. This ensures satisfactory performance in terms of time duration and power usage. Methods like buffering, caching, and event-triggered messaging facilitate the smooth operation of smart homes. The idea of connecting smart homes to the internet presents flexible solutions for managing power and converting energy forms. Our application can be extended to perform tasks such as energy management, exploring power-efficient rules for smart cities by connecting physical devices. In recent years, the Indian government has pledged to develop smart cities, and our goal is to provide a smart framework that enables not only the development but also the thriving of these smart cities. Information, derived from various sensors and analyzed by sophisticated analytical engines like PIG-based Bigdata applications, is the power that drives these cities. The upcoming era of smart cities relies on intelligent sensing power achieved through IoT frameworks, allowing communication not just between people but also with their homes and devices.

Different institutions are joining the discussion, educating state management and learning centers about the impact on the future economy, people's welfare, and service quality. State officials are exploring effective information and communication technology resources, uncovering opportunities for citizens to follow a progressive path. Transforming cities with sophisticated technology integrated into smart cities requires documenting policies, actions, projects, and programs into various modules. However, implementing this idea is challenging due to a lack of mature provisions and a focus on methods rather than groundwork and deployment. Smart cities, coined as such, should be transparent, easy to understand, responsive, and capable of coping with current and future technologies. Stakeholders in these cities must understand the environment, its manageability, adaptability, and flexibility to handle complex tasks. Effective management of such complex cities requires leadership and the ability to perform when necessary. Our research aims to test the practical implementation of a smart district and demonstrate how complementary elements can work together to create a simulation model for actual city development. We also aim to shed light on uncharacterized modules of smart cities, stakeholders' roles and responsibilities, unknown features,

and the deployment process. The idea of smart cities has captivated the Indian public and stakeholders in recent years. It represents a city that utilizes the latest information and communication technology for its development. Stakeholders' investments in smart cities often involve deploying networks within the city, allowing for more efficient management and comprehensive reporting of control systems through Big data analysis. Real-time and accurate reports generated from this Big data framework enhance the decision-making process. However, it is essential for the public to understand that participation in smart cities is not mandatory and there is more to it than meets the eye.

LITERATURE REVIEW

Imagine returning home in the evening and your house springs to life, all thanks to the advancements in sensor technology. Smart homes, also known as automated homes, intelligent buildings, integrated home systems, or domestics, are the result of recent design developments. In cryptography, both symmetric and asymmetric key encoding are used. Symmetric key encoding requires the same key for encryption and decryption, while asymmetric key encoding uses a pair of keys, a public key, and a private key, for encryption and decryption. The objective of cryptography is to ensure secure transmission of messages from the source to the destination without interception. By networking individual system modules, preset scenes can be executed to make your everyday life safe and comfortable. Imagine arriving at your house, and the garage door opens, the driveway is well lit, blinds are raised, and the alarm system is deactivated. When you leave your house, this technology ensures that your lights are switched off, blinds are lowered, lobbies are at rest, heating is turned down, and the alarm system is activated with a simple touch of a button. The door communication station at the entrance is robust, weather-resistant, and features solid metal buttons and illuminated glass nameplates. It is highly secure against tampering and can only be dismantled using a special tool. Depending on the system configuration, when the bell button is pressed in the dark, exterior lighting is automatically switched on to welcome visitors.

Optimum communication and safety are always guaranteed. The hidden camera captures sharp images, and the digital signal processor ensures excellent speech quality. The high-quality TFT color monitor inside the house displays the transmitted image, which can be shifted or zoomed in on via the onscreen display with touch functionality. The proposed system does not require a dedicated server PC and offers a novel communication protocol to monitor and control the home environment beyond basic switching functionality. With integrated full duplex operation and a digital signal processor, the system enables error-free and synchronous speech, telephone calls, and automatic calibration to ambient conditions. Active suppression of street noise optimizes comprehensibility. The indoor station has audio and video functions, and its touch screen and large push button guarantee simple and convenient adjustment and operation. Individual messages can be recorded and saved with the voice memo function, and when a message is left, an LED on the keypad flashes to indicate its presence.

When the doorbell is pressed, the camera image is automatically stored with the date and time, allowing you to determine who was at the door while you were away. The menu can be accessed by touching the info button, and stored messages are displayed chronologically. You can select or retrieve picture messages using the arrow keys. IoT technology welcomes you into the house by raising the internal blinds and switching on ceiling lights. Various scenes can be programmed using a central controller. With a presence detector, you can control room lighting, saving energy by only switching on lights when someone is present. LED pilot lights illuminate the stairs, ensuring safety even when the ceiling lights are off. The room controller sets the right mood, whether for a game of chess or a cozy evening by the fire, with just a click of a button. LED outlets help navigate through dark rooms without the need to switch on the lights. The kitchen diner, as the focal point of the house, is ideally suited for the IoT home controller. Its user-friendly touch screen allows for management of functions throughout the house.

Enabling IoT and Big data

Controlling and visualizing the central functions of your house is effortless with individually installed control panels in each room. Additionally, the intelligent facility pilot software allows control via any PC, thanks to its bundle of Windows application standard interfaces. This multi-room control enables you to listen to news in the kitchen, rock music in the bathroom, and a radio play in the children's bedroom. Smart metering is a crucial aspect of intelligent and efficient energy management. With the facility pilot, it is logical to continuously record, display, and evaluate consumption values for electricity, water, and thermal energy. This feature provides an overview of your house's security status, indicating whether any doors or windows have been opened. Network cameras are visualized, allowing you to monitor activities inside and around your house.As primary energy costs rise, sophisticated heating control systems become more important. The facility pilot simplifies this task by allowing you to adjust the thermal settings in each room based on demand and occupancy. The visualization screen displays set points and actual temperatures in all rooms, providing easy control and influence. Blinds, shutters, and curtains also contribute to heat protection by shielding against solar radiation in summer and reducing heat transmission in winter. Automatic time and weather-dependent control are highly recommended.

Lighting control through the facility pilot offers increased convenience and energy savings. In addition to switching and dimming lights from one location, the software enables the creation of individual scenarios by combining multiple light fittings and blinds in a specific area. A roof-mounted combo sensor provides weather data, which is connected to the weather statin through the facility pilot. The facility pilot can even display internet content using its browser function when connected to a network with internet access via its LAN interface. Whether simple browsing or complete remote interrogation of your building functions, the facility pilot offers a wide range of capabilities. An energy-saving automatic switch ensures that lights are turned on when someone is present. To enhance the landscape, treated water will be filtered by grass, allowing its reuse throughout the city. Nutrient uptake from the grass will contribute to the beauty of the landscape. Special trees, such as date palms, will be planted in the smart city, serving both aesthetic and functional purposes. For example, date palms need to be pollinated in the spring, and the dates can be harvested in August. Other trees like avocado, papaya, pomegranates, mulberry, and fig trees will benefit from the shade provided by the palm trees. Irrigation and treatment systems will be installed using pipes across the city, utilizing treated sewage for watering these plants.

Smart City Energy Management

The smart grid revolutionizes the way electricity and information are exchanged between utilities and customers. It is an evolving network of communications, controls, computers, automation, and innovative technologies working together to enhance the efficiency, reliability, security, and sustainability of the grid. With the integration of newer technologies like wind and solar energy production and plug-in electric vehicle charging, this smart grid replaces aging infrastructure and enables utilities to effectively communicate with consumers to manage their electricity needs.The smart home plays a crucial role in this system, allowing consumers to actively manage their electricity usage. Through smart meters, which measure a home's electricity consumption more frequently, utilities can provide customers with accurate information to effectively manage their electricity bills. Inside the smart home, a home area network (HAN) connects smart appliances, thermostats, and other electric devices to an energy management system. Smart appliances and devices can adjust their operation schedule to reduce electricity demand on the grid during critical times, leading to lower energy bills for consumers. These devices can be controlled and scheduled remotely over the web or through other interfaces like a TV.

Analyzing different scenarios helps evaluate the impact of uncertainties related to renewable energy sources on the optimal planning solution. While renewable resources like wind and solar power are sustainable and growing sources of electricity, their variable nature adds complexity to grid operations. The smart grid provides the necessary data and automation to efficiently integrate solar panels and wind farms into the grid, optimizing their energy production and utilization. To meet the constantly changing energy demands, utilities must manage power plant operations based on the required power at different times of the day. The cost of delivering power varies depending on the time of day it is consumed. Peak demand times, when electricity usage is high, require additional and often

less efficient power plants to be activated, resulting in higher delivery costs. By actively moderating electricity usage, especially during peak demand times, utilities can reduce operating costs. Through the smart grid, utilities can incentivize consumers to shift their electricity usage away from peak hours, leading to a more evenly distributed electricity production throughout the day.

Deployment of grids in smart cities

India is poised to enter a new era of growth and technological advancement, but the increasing energy demand poses a significant challenge. It is projected that India's energy demand will triple in the next decade, requiring efficient and sustainable solutions. Smart grids offer a way to meet this growing demand for electricity while enhancing the efficiency of power transmission and distribution networks. The Ministry of Power, Government of India, has assigned smart grid pilot projects to state-owned distribution utilities. The New Energy Technology Development Organization (NEDO), an agency of the Government of Japan, has offered to fund the Smart Grid project in India through a Japanese government grant. NEDO has partnered with a consortium led by Fuji Electric Japan to implement this project, leveraging the strong cross-cultural and business relationship between India and Japan. Fuji Electric is at the forefront of developing new energy technologies in India. Smart grids leverage digital technology to create greener and more efficient energy transmission and distribution systems. Fuji Electric Japan and Fuji Electric India are working together to implement the smart grid project in an Indian state.

Consistent and reliable power quality is crucial for business success. India faces frequent power fluctuations and inconsistent supply, hindering the productivity of businesses. Machines equipped with sensitive electronic components suffer damage and malfunctions due to voltage fluctuations. Stable power supply would extend the lifespan of machines, eliminating the need for large servos and constant voltage transformers. Furthermore, a continuous and reliable electricity supply would reduce transmission and distribution losses, which currently stand at a high 30% in the country. Strengthening the electrical network and improving resource management are essential to address these issues. Smart grid technology can seamlessly integrate into the existing electrical grid infrastructure. Any faults or issues along the power transmission line would be instantly reported to the grid, allowing for prompt repairs. With a smart grid, the power supplied to consumers would have uniform quality, without voltage fluctuations. Additionally, as energy consumption predominantly occurs in cities, which are hubs of economic activity, implementing smart grid solutions in urban areas would be particularly impactful.

Transcending the Era of Smart Homes

The future of urban transportation is being reshaped by advancements in technology, including autonomous cars, buses, and on-demand shuttles. These connected vehicles hold the potential to solve major transportation challenges in urban areas. The Smart City challenge in India encourages midsized cities to apply for resources and leverage technology to address transportation issues. The winning city will have the opportunity to implement bold, data-driven ideas that make transportation safer, easier, and more reliable.The convergence of technology and transportation offers tremendous opportunities for communities, but local decision-makers need to envision how these tools can enhance mobility, reduce climate change impacts, improve livability, and enhance safety. The Smart City challenge aims to stimulate conversations and encourage innovative solutions across India. Technologies that help prevent collisions are being developed and can be applied to urban environments where pedestrians, cyclists, and vulnerable road users coexist. By collecting data on near-collisions and analyzing patterns, infrastructure planners can make informed decisions to reduce future accidents.

Cities serve as living laboratories for testing new capabilities to solve problems. However, cities often lack sufficient resources to implement large-scale initiatives. International companies work with cities on pilot projects, including in Indian states. While there is global interest in future smart city solutions, implementation depends on funding and finding the right business models. For instance, upgrading street lamps to energy-efficient LEDs presents an opportunity to add additional sensors that can detect human presence or monitor traffic flow. However, determining who pays for these upgrades and defining sustainable business models remain challenges. The connectivity of everything is a fundamental aspect of smart cities. However, network infrastructure ownership and provision

become public policy issues. Cities need to establish decision-making offices and address spectrum challenges. Municipalities that lead in these areas can become exporters of solutions. Connectivity is crucial for running a city efficiently, and when everything is connected, bandwidth demand increases significantly. Ensuring open and accessible urban data for all stakeholders is a complex problem that requires coordination. As cities undergo modernization, it is essential to prioritize connectivity in infrastructure, such as lamp-posts and streetlights. Access to data and connectivity should be universal, enabling effective use of urban data to drive informed decision-making.

RESULTS AND DISCUSSION

The aim is to establish a theory that latest advancements like IoT, Cloud and Big data can be used as a bedrock for sustainable smart cities in India. In this chapter we would like to demonstrate the use of IoT, Cloud and Bigdata using a prototype model for future smart cities in India. For the said purpose we have divided our research work into three phases among which we will discuss Phase-I and Phase-II in this chapter and Phase-III in the Results chapter . Figure 1 above illustrates several crucial aspects of the infrastructure that will be incorporated into future smart cities in India, as envisioned through our research. The following are explanations for the buildings included in the layout: EDM Centre: EDM, or Electronic Data Management Centre, serves as a centralized hub for data acquisition from various sources across the city. This facility plays a vital role in a smart city scenario. With the presence of IoT-based sensors throughout the city, there is a significant influx of sensory data related to monitoring, retail market transactions, banking, and network transactions, among others. The primary purpose of the EDM Centre is to properly store, filter, and analyze this vast amount of data. Staff members at this centre are responsible for maintaining city records, issuing certificates, and providing services to stakeholders. Essentially, the EDM Centre functions not only as a municipal corporation hub but also as a mega data centre equipped with advanced equipment and sophisticated software for analysis and reporting. The idea is to utilize Big Data technology in this centre, ensuring its integration with the IoT network spread across the city. Establishing an EDM Centre is essential in a smart city to ensure efficient data management, as a lack of streamlined data management systems could lead to chaos in such an advanced urban environment. Connecting the EDM Centre with the city's infrastructure enables continuous monitoring and contributes to the overall sustainability of the smart city vision.

CONCLUSION

Our goal is to establish sustainable smart cities in India by leveraging technologies like IoT, Big Data, and Cloud computing. We recognize that data is a crucial resource for achieving sustainability and propelling us into the future. Cities worldwide are progressively integrating technology into every aspect of their operations, including public transportation, IT connectivity, water and power supply, sanitation, solid waste management, urban mobility, governance, and citizen participation. This integration utilizes various cutting-edge technologies, from Big Data to the Internet of Things. By the year 2050, it is estimated that 70% of the global population will be residing in cities, occupying less than 2% of the Earth's surface. This rapid urbanization presents numerous challenges, including pollution, infrastructure, accessibility, traffic congestion, mobility, safety, and public health, to name a few. The development and integration of innovative technologies such as the Internet of Things and Artificial Intelligence offer multifaceted solutions, which are known as smart cities today. Smart cities are highly interconnected urban areas equipped with advanced technologies to enhance the lives of their residents. In India, there are still neighbourhoods struggling with limited access to electricity. In a smart city, sensors would be deployed to analyze electricity usage across various sectors, allowing for optimized energy distribution throughout the power grid. This would result in fewer power outages and a more balanced energy distribution system.

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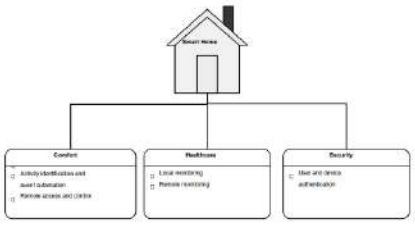

Fig 1: Desired for decipherment

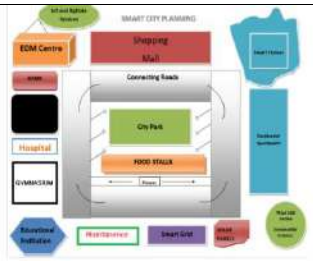

Fig 2 :layout of EDM Centre

Fig 3: Smart city prototype model developed at IGNTU research centre