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Design of Quality of Experience-based Green Internet Architecture for Smart City

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Abstract

In Smart City (SC), things can connect with humans intelligently through the Internet of Things (IoT). IoT and ecological sensors will enable the detection of pollutants, contributing to developing environmentally friendly SC. Green Internet Architecture (GIA) in SC ensures the long-term viability of friendly spaces by enabling autonomous and intelligent sustainability practices through collaboration. Governments and organizations worldwide are promoting the significance of reducing energy usage and carbon emissions while highlighting the relevance of using GIA in SC. Several SC layouts connected to the IoT have previously been proposed in the literature. However, this study introduces the "Green Internet" notion of providing a friendly setting that focuses on conserving energy in SC. This research presents a suggested design for a GIA in SC. The main objective is to minimize energy usage at every level and ensure the implementation of IoT in a friendly manner. The suggested GIA is founded on a cloud-based system that diminishes hardware usage with Blockchain technology.

Keywords: Quality of Experience, Internet Architecture, Smart City, Internet of Things.

1 Introduction to Internet Architecture and Smart City

Green Internet is defined as a network, or a network of systems, that allows remote accessibility, perception, manipulation, or control of actual or virtual items or procedures in real-time, either by humans or computers (Alsamhi et al., 2021; Abduljaleel et al., 2024). It is widely understood that the response time of humans to auditory stimuli is around 100 milliseconds, whereas the response time to visual stimuli is around ten milliseconds. These align with latency indicators of the current mobile

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Network and Internet of Things (IoT) (Khanna & Kaur, 2020). To successfully perform green steering and manipulation of an item while concurrently perceiving its reaction through sight or sound, it is necessary to accomplish a round-trip delay of 1 ms. Thus, implementing green transmission in the Green Internet ensures a round-trip delay of 1 ms, along with carrier-grade resilience and reliability (Rosa et al., 2023).

A Smart City (SC), facilitated by data and communication technology advancement, efficiently achieves diverse urban tracking, administration, and improvement objectives (Kirimtat et al., 2020). Despite developing several designs and approaches for SC, they still need to be solved. SC structures are mainly based on the IoT using electric cars (Raman & Ramachandaran, 2023). Given that the primary objective of a SC is to deliver real-time, dynamic, and smart urbanization amenities to end-users, it is crucial to determine, measure, and enhance customer satisfaction. Quality of Experience (QoE) is the total desirability of an application or service objectively judged by customer experience (Raman et al., 2023). According to the International Telecommunication Union (ITU), it is an essential assessment for SC offerings. Thus, it is crucial to prioritize QoE when developing, designing, and expanding apps for SC in logistics applications (Prashanth et al., 2024). A previous study suggested a Green Internet Architecture (GIA) to provide reasonable QoE in a SC (Mishra & Kumar, 2023). Multiple approaches have been proposed to address the difficulties arising from different situations in SC, considering end-users quality of experience.

2 Background and Related Works

Current research on the future internet has concentrated on network designs that facilitate hosting internet applications that effortlessly link consumers with various offerings from any device or node (Surendar et al., 2024). The authors examined the issues the Transmission Control Protocol (TCP)/ Internet Protocol (IP) building faced (Machora, 2024). They proposed a Service-Oriented Architecture (SOA) that transformed the network from a mere transport layer into a service queue (Rumez et al., 2020). This novel design integrated transmission, retention, and computation features to establish a more safeguarded and reliable system to control its states.

The nascent domain of Multi-Access Edge Computation (MAEC) poses a substantial hurdle in tackling the problems associated with the amalgamation of service buffering and offloading tasks (Cruz et al., 2022). The authors suggested an optimization-based strategy that emphasized the QoE for consumers by striking a balance between service latency and computational resource expenses (Saleem et al., 2020). Named Data Networking (NDN) is receiving recognition as a secure authentication system for intelligent homes, placing it at the cutting edge of these advanced internet infrastructures (Stergiou et al., 2020). The researchers focused on two primary issues with NDN: establishing a reliable connection between the network and newly added devices and guaranteeing that only users can access the system's information. These cutting-edge technologies emphasized the increasing demand for sophisticated safety precautions in following internet infrastructures.

Metaverse systems can perform Augmented Reality (AR)--based remote robotic operations and surgery (Makhataeva & Varol, 2020). The practical application of fields like digital fingerprints, bitcoin, and Explainable Artificial Intelligence (XAI) poses difficulties in the real world. During the first stages of the Metaverse's development, it is crucial to incorporate security and confidentiality protocols into the design process to provide an added level of service reliability for its users. Although there are difficulties in growing the digital infrastructure, there needs to be a functional computer system with sufficient processing and network capacity. Access technology will only be compatible with developing 6G mobile networks, which are experimental and not yet widely accessible worldwide (Yuan et al., 2020). To properly initiate the Metaverse, it is crucial to comprehend the connectivity and interoperability between the real and virtual realms. It is essential to consider the ability and capacity of the Metaverse combustion engines to grow, as the necessary processing power differs from the demands of the social media foundation. It is crucial to consider tactics such as efficient processing and operation to reduce the expenses associated with handling, storing, and connectivity. These solutions might use automatic Artificial Intelligence (AI) based methods, which need more consideration.

3 Proposed Green Internet Architecture

The research presents a QoE-driven GIA structure designed for SC, as seen in Figure 1. The architecture comprises five distinct levels: the sensor level, transmitting level, storage level, computation level, and application level.

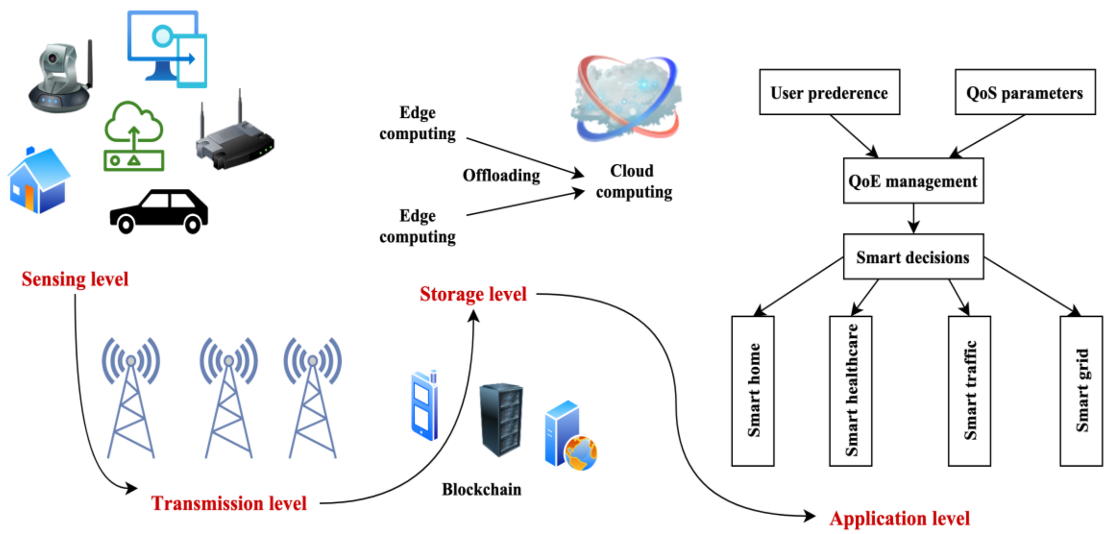

Figure 1: The Proposed Green Internet Architecture Design

3.1. Sensing Level

Green perception involves providing people the ability to interact with haptic gadgets physically. A linkage-based structure, including a robotic arm connected to a stylus, is the prevailing design for haptic gadgets. Green data typically consists of two distinct categories: kinesthetic and green feedback. Kinesthetic feedback includes data on force, acceleration, location, speed, and other related factors sensed by the human body's muscles, ligaments, and tendons. Green response refers to the sensory information related to surface roughness, friction, and other similar factors that the mechanical receptor perceives in people's skin. The study of green data allows for the acquisition of users' subjective experiences, including feelings of optimism, pessimism, bliss, agony, unconsciousness, and ritual, which are strongly linked to the QoE.

The design's suggested sensing component's primary function is to gather big data from dispersed sensors in SC (Subrahmanyam et al., 2024). To include green data, it is necessary to integrate green sensors and equipment with actuation into the current sensing framework to establish a novel detecting level. Thus, gadgets at the detecting level collect both audiovisual and green input. The initial data is subjected to pre-treatment, including sanitation, sorting, and combination, to facilitate further delivery and analysis.

3.2. Transmission Level

When incorporating the GIA into SC communications, it is essential to have a highly responsive and stable connection. The very responsive connection ensures that users of the GIA will not encounter cyber-sickness. Ultra-reliable connection pertains to the capacity to provide a necessary function or efficiency for a specific period, considering the diverse requirements of various programs and services. Modern Orthogonal Frequency Division Multiplexing (OFDM) oriented systems have challenges achieving a 1 ms round-trip latency, which is necessary for ultra-responsive connection. Revamping the communication protocols in the signaling layer is imperative. Using frequency diversity across numerous independent lines, carrier-grade dependability meets the growing need for ultra-reliable connections. Interband frequency aggregation methods and coordinating multipoint broadcasts can establish multiple independent connections.

3.3. Storage Level

Due to the increasing amount of data generated by green instruments and other smart sensors, the current central database needs to be improved for data storage. It is imperative to have shared storage that relies on a shared database. Storing data in dispersed data centers, such as edge data centers, significantly cuts connection and computation time for end-users when accessing their information in virtual teams (Subrahmanyam, 2019). Data maintained in dispersed edge information centers is replicated in the centralized databases. This can efficiently mitigate system crashes during an edge computing failure, enhancing the system's overall resilience.

Blockchain Technology (BT), which forms the foundation of the storage level in the suggested design, functions decentralized and provides the same functionalities verifiable without relying on an authoritative source (Gad et al., 2022). Utilizing decentralized and mobile preservation, the BT can offer security measures for complex transactions and adapt its processing methods based on delay needs and big data analytics. Applying decentralized data storage and blockchain significantly contributes to preserving and safeguarding users' private data in the GIA via the SC.

3.4. Computing Level

The computational level is positioned between the storage and application levels, serving as a bridge between them. Existing cloud-centric computing architectures need the transport of big data streams from loT gadgets to a centralized cloud infrastructure. The challenges of real-time computing and energy usage in the centralized cloud infrastructure are present. In contrast, edge computing eliminates the need to transfer multiple computing processes to consolidated cloud data centers, lowering communications latency and computational burden on the cloud infrastructure. The limited computational capacity of edge data centers might lead to overload issues. The current cloud or edge computing solutions will not be applicable in the SC if the GIA is implemented because of the need for minimal latency, high dependability, and enhanced user QoE.

3.5. Application Level

The application level is an intermediary between the computational level and the end-users. This level executes intelligent decision-making processes, including network optimization and demand management tasks. Analyzing data and users' input can facilitate astute decision-making and effective administration. At the application level, acquiring user preferences and generating a user graph can be acquired by extracting green and pre-existing audiovisual data. The correct perception of users' QoE is achieved by integrating user preferences with Quality of Service (QoS) metrics collected from the terminals. Once QoE monitoring and intelligent decision-making are implemented across different application contexts, users' QoE will ultimately be enhanced.

3.6. Challenges

Several significant challenges arise while making changes to a city, which are outlined below:

3.6.1. Privacy Issues

The intelligent network in the suggested GIA has successfully met the computer's power consumption needs, such as those particular to specific applications. The application lacks access to information. Intelligent networks lack immediate access to applications and customer information, as an operating system facilitates these interactions. It is associated with the operating system that transfers confidential forms of data. It is the sole aspect of electricity consumption.

3.6.2. Compatibility issues

Currently, many devices are operating on an incompatible operating system. The research employs the bright shell to make the current operating system compatible. By adopting this approach, the system can enhance the efficiency of existing systems' power consumption. It should be highlighted that the intelligent shell addresses the problems arising from the wide range of systems now in use.

3.6.3. Energy-aware society

Despite advancements in green software and conserving energy, the success of the smart system framework depends on people's willingness to embrace and accept that an urban, global SC is the only solution to the global warming crisis. The ultimate responsibility lies with the worldwide population, as SC can only fulfill its purpose without knowledge and awareness. These qualities are necessary for change to occur.

3.6.4. Environmental policies

It is necessary to establish national policies that promote the development of GIA software products and encourage customers to choose them over non-green alternatives. The transition to a fully GIA system will significantly impact the market. It is imperative since the general people would only support the new GIA structure if it benefits them financially, particularly in developing nations. Because the average individual only considers economics, environmentally friendly behaviors are neglected.

3.6.5. Economy

The significance of the economy's function can be comprehended through the observation that rural residents are compelled to migrate to cities, placing immense strain on existing urban areas and prompting the pursuit of economic prospects that necessitate the establishment of new urban centers. This is one of the factors contributing to the growing prevalence of SC, as it addresses the financial disparity between urban and rural communities. The research has suggested using a smart system to enhance energy efficiency and reduce expenses. More components within the intelligent system handle tasks such as processing, data collecting, and network maintenance.

4 Simulation Evaluation and Findings

This section presents simulation findings that validate the methodology developed for assessing QoE of GIA systems. The outcome of this assessment will directly influence the final QoE administration. To evaluate the efficacy of the BT structure, the research has chosen two alternative approaches for comparison: Support Vector Machine (SVM) (Pisner & Schnyer, 2020) and Decision Tree (DT) (Costa & Pedreira, 2023). The Spark system incorporates SVM and DT with the BT (proposed GIA) to achieve customer preference prediction, ultimately obtaining the QoE score.

To meet the demands of minimal latency and excellent dependability in the Green Internet, the research evaluates these three methods' effectiveness based on accuracy and precision. Training time refers to the period required for establishing the structure of an algorithm and determining its parameters (Wang et al., 2023). It is used as a metric for assessing efficiency. Accuracy is the ratio of relevant examples between the retrieved cases, while recall is the ratio of appropriate instances that have been recovered over the entire number of relevant examples.

Table 1: Performance Analysis of Different Methods

Database	Model	Training duration (sec)	Accuracy (%)	Precision (%)
1	SVM	243.2	43.7	52.7
	DT	3243.2	48.4	57.4
	GA	35.2	74.2	83.2
2	SVM	384.2	52.3	64.2
	DT	4283.1	56.4	69.7
	BT	68.4	61.2	73.1
3	SVM	532.8	58.4	62.3
	DT	5942.5	61.5	67.4
	BT	47.2	76.3	79.5

Table 1 displays the results of a comparison of BT (proposed GIA), SVM, and DT in terms of their effectiveness in predicting user preferences. The result displays Database 1~3, consisting of actual data from ground stations (traffic statistics for multimedia services) and interaction with smart interfaces (information about user program-watching behaviors and network conditions). These datasets were gathered from three distinct districts in a prototype SC. The precision and accuracy of SVM exhibit the lowest performance. The accuracy and precision of BT with proposed GIA are more excellent in Database 1 and Database 3 but somewhat lower in Database 2 when juxtaposed with DT. The BT with GIA training period is relatively rapid. But, it can significantly decrease the time it takes to compute while ensuring correctness.

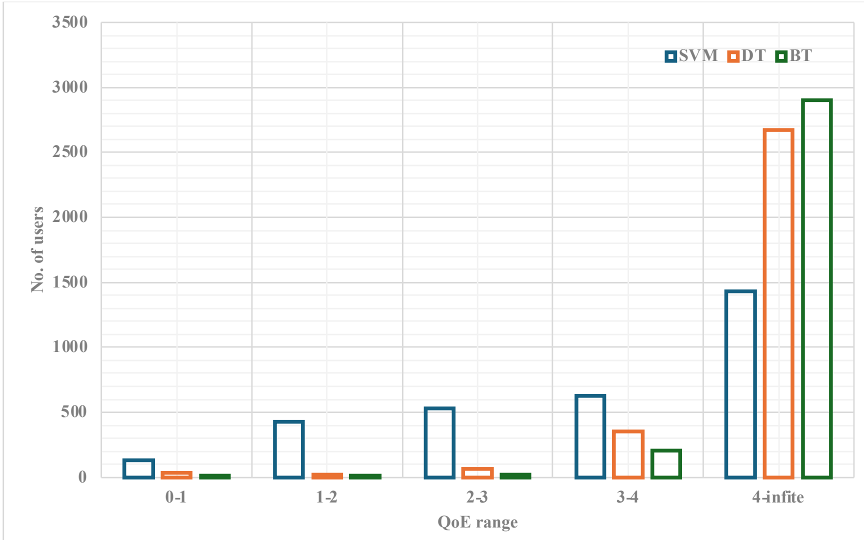

Figure 2: QoE Performance Analysis

Figure 2 compares QoE distributions in the suggested design to those based on DT, BT, and SVM. Since the accepted QoE assessment technique is based on a sigmoid operation, the resulting QoE is not a whole number. The quantitative dispersion of QoE is provided in the intervals (0-1), (1-2), (2-3), (3-4), and (4, infinity). According to the characteristics of the sigmoid operation, the highest QoE is achievable, according to the database, approaching a value of 5 but not reaching precisely 5. Here, "infinity" represents the maximum value of QoE as a limit. Based on this number, it is evident that 90 percent of consumers achieve a QoE rating greater than 3 for both DT and BT (proposed GIA) networks.

Moreover, in terms of the percentage of customers with a QoE rating greater than 4, the efficiency of the BT method surpasses that of both the SVM and DT systems. Given its benefits in terms of efficacy and productivity, BT will be a suitable framework for SC once the GIA is integrated. It is particularly well-suited for the computing level of the suggested construction, namely in the edge data centers.

5 Conclusion and Future Scope

Telecommunication systems are crucial in the functioning of SC. The product must possess high reliability and availability while being adaptable, cost-effective, and environmentally responsible. To meet these challenging criteria, a novel SC design is suggested, which would utilize cloud-based IoT smart technologies to optimize energy usage and promote environmental sustainability in urban areas. Using the suggested GIA methods, SC provides a diverse range of services. Using cloud-based services, visual communication instruments, and high-speed broadband communication systems in SC can enhance business operations in both corporate and government sectors. Networked sensors in GIA with SC employ wireless technology to provide data regarding the movement of commodities, machinery conditions, and the surroundings with blockchain technology.

They enable the utilization of remote control. GIA allows the deployment of SC that prioritizes safety, security, and ecological sustainability. The sensor layer facilitates data transmission from various sensors to users. GIA enables users to utilize multiple applications over a cloud platform and perform data processing. In the future, promoting collaboration across communities can be facilitated by the increasing sophistication and intelligence of actuators and sensing devices, communication methods, and control mechanisms. It is imperative to provide creative approaches for computing and communication technology, flexible networking, and dependable software engineering while minimizing energy consumption. Another viable study area is to forecast a trajectory for incorporating cutting-edge innovations into current SC structures and apps, enhancing their capabilities in GIA.

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Dr. Arasu Raman, a senior lecturer in Marketing and Management at INTI International University, holds a Ph.D. in Business Administration with a specialization in Marketing. With over 27 years of teaching experience, he is certified as a Professional Trained Teacher by the University of Hertfordshire and in Case Teaching by Harvard Business School. Dr. Arasu has published 26 research articles on entrepreneurship, digital marketing, and marketing information systems. He is renowned for his innovative curricula and collaborations with multinational companies.

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Dr. Anantha Raj Arokiasamy, an Associate Professor at INTI International University, has over 20 years of experience in educational leadership and management in Malaysia's private higher education institutions. With a bachelor's degree in business administration, Master of Arts in International Business, MBA, and Ph.D. in Educational Management and Leadership, he has authored books and published over 80 academic papers, influencing global educational policy and leadership development initiatives.

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Dr. Priya Sukirthanandan, has over 25 years broad experience in driving wide spectrum corporate legal advisory, commercial and corporate litigation towards safeguarding the interest of organizations as well as individual clientele. Well versed in the areas of corporate due diligence, disputes resolution along with agreements drafting and vetting coupled with outstanding negotiations acumen. Furthermore, having over 15 years' extensive experience across academic administration as well as lecturing and teaching. Well versed in the areas of academic management, leadership initiatives in strategic planning, policy and curriculum development, teaching method evaluation and improvement, student retention along with industry collaboration.