Research Article

Extracting Intelligence from Large-Scale IoT Data: A Real-Time Analytics Architecture

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Abstract

The proliferation of Internet of Things (IoT) technology and the exponential growth of big data necessitate the implementation of intelligent analytical systems within ubiquitous computing environments. Big Data encompasses the vast quantities of information produced by numerous interconnected sensors operating within communication networks. These networked systems demand efficient oversight and coordination across their communication infrastructure. This creates significant analytical challenges regarding the efficient collection, analysis, and supervision of massive datasets from intelligent IoT sensors while maintaining minimal energy consumption. Although smart cities represent a broader IoT ecosystem, this research concentrates on smart office infrastructure to examine sustainable and efficient sensor data management. Our research objective is to demonstrate the capabilities and potential of advanced big data analytics within intelligent office environments to improve operational efficiency. We integrate four compelling technologies—sensors, cloud computing, big data, and IoT—to establish beneficial synergies for enhanced functionality and implementation. Our proposed architecture for sensor service management provides real-time estimates of energy consumption for each node within an intelligent communication network. We evaluate our real-time solution against conventional systems using relevant throughput metrics and energy utilization parameters. The results indicate that our real-time intelligent office solutions can guide the development of efficient smart workplace environments.

1 Introduction

The concept of the "Internet of Things" (IoT) has revolutionized the digital landscape through its innovative integration with substantial advances in computing and communication technologies [1]. IoT-based systems have transformed daily work operations by providing intelligent and efficient environments through device interconnectivity, autonomous operation, collaborative outcomes, and comprehensive measurements [2]. The IoT plays a vital role in monitoring and controlling "Intelligent Office Management" systems [3]. The massive data volumes (ranging from terabytes to hundreds of petabytes) generated by these networked devices constitute what we term "big data" [4]. The rapid convergence of microelectromechanical systems (MEMS), wireless networks, and digital electronics necessitates IoT management of the enormous data volumes produced by both industrial and individual users [5]. This IoT expansion has profoundly influenced the big data ecosystem. Nevertheless, numerous opportunities emerge for real-time analysis of the substantial data generated by IoT sensors [6]. These opportunities encompass IoT applications in residential, social, healthcare, and industrial contexts within pervasive or intelligent environments through wearable devices or remote monitoring systems. However, energy consumption in smart offices remains underexplored [7]. As technology advances, big data analytics becomes increasingly complex due to data collection and processing from diverse sensors within IoT environments. Industry research forecasts that big data benefits will drive market growth to 125 billion US dollars by 2019 [8]. IoT analytics encompasses the processes involving extensive data extraction from IoT sensors, revealing new insights, correlations, patterns, and previously unnoticed trends [9]. Big data analysis facilitates control and management for both individuals and organizations. IoT-based Big Data emerges from the convergence of these two distinct technological domains [10]. Figure 1 illustrates the architecture of intelligent massive IoT systems.

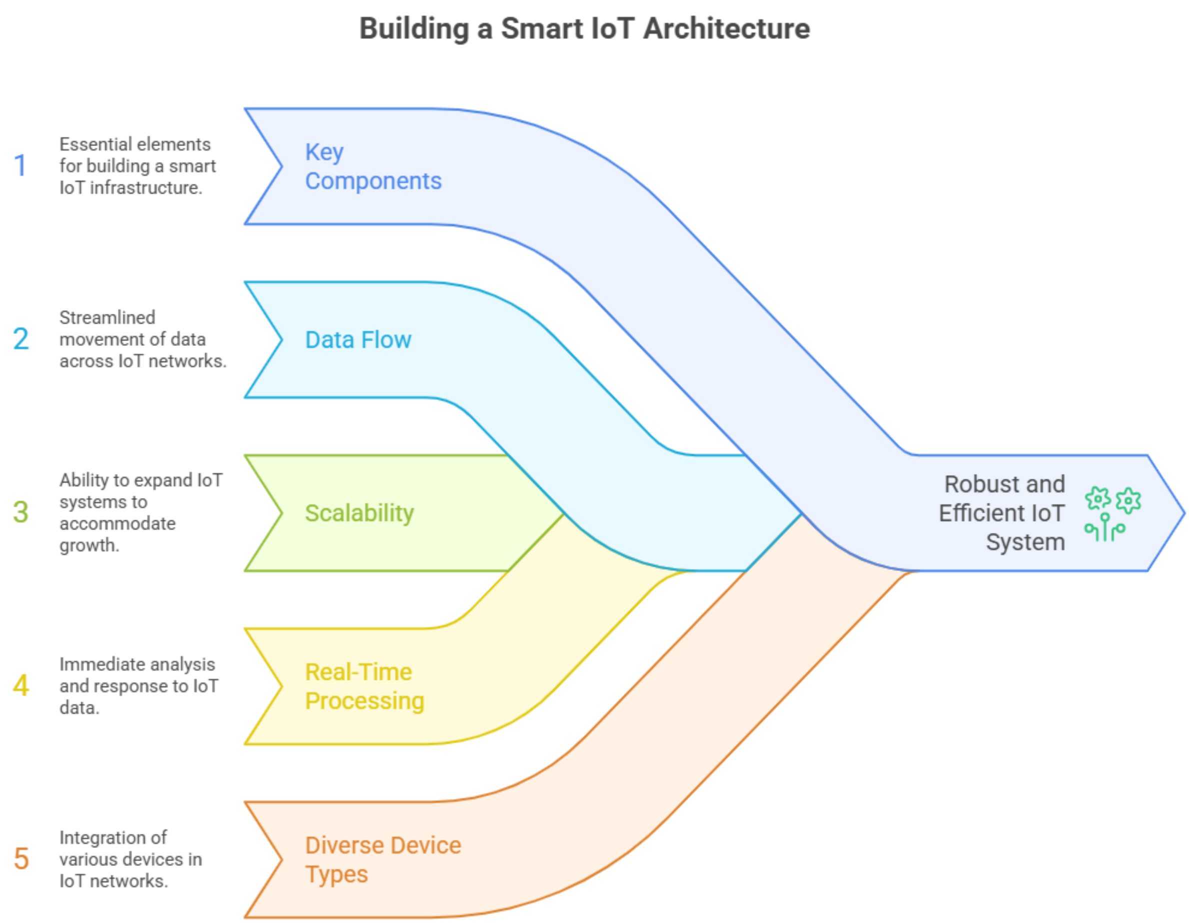

Figure 1: Smart Big IoT Architecture.

Wireless Sensor Networks (WSN) technology has been implemented to establish IoT environments supporting this initiative. It typically employs limited wirelessly connected sensing devices communicating via the internet with constrained resources [11]. These compact devices, connected to other networks through routers and internet infrastructure, are also called motes (nodes) of wireless networks, designed to collect and transmit data and information. These IoT nodes provide simultaneous, continuous data streams from multiple endpoints, offering advantages including real-time network failure detection and ease of installation and operation [12, 13]. However, the primary power limitation for these sensor nodes typically stems from their batteries. Various energy-efficient solutions, including wind, water, and solar smart grids, have been implemented to address this challenge [14, 15].

Data analytics is essential to address this issue and deliver efficient data services through various sensors in IoT environments by determining energy consumption for each node. According to [16], the requirement for real-time (efficient) analysis of this interconnectivity leads to substantial data management solutions, utilizing unique requirements such as volume, velocity, and variety beyond conventional network infrastructure and processing capabilities [17]. Our research goal is to integrate all aforementioned technologies to provide an effective solution supporting smart systems in environments that are affordable, comfortable, secure, welcoming, and scalable [18, 19]. This study focuses specifically on intelligent offices due to numerous IoT data management applications, with relevant work discussed in [20]. The main contributions of the proposed model include:

- Creating an intelligent, energy-efficient communication network capable of collecting and processing large sensor data volumes while maintaining minimal electricity consumption as this study's primary purpose.
- This research combined four compelling technologies—IoT, Cloud Computing, Analytics, and Big Data—with important sensor visualization foreshadowing predictive care mechanisms.
- This study provided the analytical sensors' service management framework for IoT layers of smart offices.
- This study compared each node's throughput and energy consumption with typical systems. This represents the first effort to offer low-power, real-time estimation for office intelligent communication networks.

This article is structured as follows: Section 1 covers the background and motivational perspective. Section 2 provides a concise literature overview covering survey articles published in the IoT and big data analytics fields. Section 3 presents the contribution. Section 4 conducts a comparative analysis. Section 5 discusses IoT network criteria. Section 6 presents the proposed architecture for sensor service management. Sections 7 and 8 implement Contiki OS and evaluate results according to efficiency standards. Section 9 provides an ideological perspective for future research as we conclude the report.

2 Related Work

IoT encompasses various innovative trends and technologies facilitating the integration of numerous existing technologies, including Bluetooth, Wi-Fi, RFID, Zigbee, and Wibree [21]. Technologically advanced industrialized nations have realistically adopted IoT to enable citizen connectivity for enterprise development. Research scholars have comprehensively surveyed and examined diverse big data analytics and IoT challenges across various applications in available literature [22, 23]. While different technologies are employed to construct domain-specific intelligent environments, identifying and determining communication network effectiveness remains a significant challenge [24]. Despite numerous previous studies, we found that the real-time effectiveness of intelligent and robust offices has not been explored regarding IoT and big data analytics. The primary objective is to understand various approaches used in managing and controlling sensor-generated data collection. An Integrated Information System (IIS) based on Big Data, Cloud Computing, IoT, and Geo-Informatics was proposed by [25] for environmental monitoring and management. Various embedded sensors and databases were utilized in the data collection process. A highly accurate correlation between multiple environmental factors was discovered, demonstrating the proposed system's effectiveness [26, 27].

A survey by [28] demonstrated that various IoT technologies are employed for monitoring purposes. While implementation details are not provided, [29] addresses energy harvesting reduction in smart homes using detection techniques and control strategies to observe real-time occupancy status from sensors. Real-time estimation of minimal energy usage is included. Reference [30] presented a proposal for an electrically supported real-time data collection system for e-bikes. The e-bike system incorporates multiple wireless sensors and GPS units, effectively providing contextual data. The proposed model's implementation was tested on thirty cycles, yielding positive results for real-time data perception, demonstrating IoT efficiency in cycling environments. Georgia Tech developed a "track-stitching" technique to identify and measure various smart environment activities using pressure, optical, and RFID tags. A pattern-matching technique was developed to identify various objects and locations.

Consequently, [31] suggests using a sequential learning model in the Mav project, combined with Independent Lifestyle Assisting (ILA) to determine multiple pattern behaviors in smart environments. The authors included several industrial applications for this technology, resulting in effective surveillance [32]. Beyond the mentioned literature, current smart office research focuses on traditional service management systems. Efficient, sustainable, and intelligent interconnectivity of office objects is also necessary [33]. Most work in currently available studies has focused on data processing from laboratory-based offices. Following scalability and applicability requirements, traditional RDBMS solutions were employed for constraints, processing, and storage [34, 36]. Since Pakistan lacks IoT establishments, this issue must be addressed by obtaining accurate measurements of intelligent, networked workplace environments. We must investigate creating sensor-based, networked smart offices with effective and sustainable network connections using recent analytical big data developments [37]. Most smart office applications inadequately describe and focus on sensor intercommunication and performance. How were individual events determined? Most custom protocols, such as Data Distribution Service (DDS) and Message Queue Telemetry Transport (MQTT), operate in the topology background and are specific to sensor-equipped devices [38, 39]. To understand business insights in intelligent workplaces, determining proper sensor data collection and processing methods is imperative. This data can inform future findings and research for examining and analyzing critical decisions and events. Big data analytics is required for the office's evolutionary processes [40]. Therefore, our goal is to outline the big data analytics promise and potential in smart offices to enhance daily operations.

This research utilized a cloud server to construct a method for collecting time series or massive, continuous data streams from optical sensor movement. This research examined interconnected node energy consumption over various periods, then analyzed anomalies using efficient analytics and cloud computing benefits, including increased storage capacity, efficiency, affordability, scalability, durability, reliability, and flexibility to enable preventive care mechanisms in smart offices [41, 42]. Currently published literature does not provide each smart office node energy consumption relevance. Since every communication network node consumes substantial energy, energy consumption represents a significant challenge [43]. A comparison between our proposed method and standard communication systems is provided. Our proposed solution contributes to efficient services and minimal energy usage.

3 Materials and Methods

IoT's exponential growth means data processing, administration, and storage must adapt to analyze sensor data. This study must identify the most promising requirements for real-time smart office deployment to manage massive data volumes produced by heterogeneous IoT devices (sensors). Table 1 lists these specifications. All aforementioned requirements must be met to construct smart office networks. These goals were accomplished following successful implementation. The authors selected Contiki OS, offering various low-power and affordable hardware solutions. Multiple sensors are connected to each remote node, providing data across various time intervals. This study created various topologies following specifications to develop intelligent networks.

As shown in Figure 2, we created an intelligent massive IoT device architecture networked to facilitate effective data transfer from remote sensors. The IoT framework comprises three divisions: Perception, Network, and Application layers. Each framework tier executes necessary operations for network communication [44]. First, the framework's lowest layer is the perception, sensing, or recognition layer [45]. This layer's primary function is sensor data acquisition. It gathers useful information from IoT networked environments, including RFID, WSN, real-world objects, heterogeneous devices, temperature, humidity, lighting, etc., then converts actuator data into a digital representation. It facilitates interconnectivity by providing a distinctive identity for real-world objects, devices, or things for communication across short-range technologies, including RFID, Bluetooth, Low Power Personal Area Networks (LoWPAN), Near Field Communication (NFC), and Bluetooth as communication layers [46]. Various communication technologies connect IoT devices and assist in data aggregation, including

Table 1: **Experimental Requirements**

Sr. #	Parameters
1	IoT Connections
2	Big data
3	Cloud Server for Storage and Virtualization
4	Big Data Management
5	Benchmarking Contiki OS
6	Low Power Consumption
7	Sustainability
8	Efficient Data Collection and Processing

Global Positioning System (GPS), bus, Wi-Fi, microwave ovens, RFID, ZigBee, HDTV actuators, and Barcodes [47].

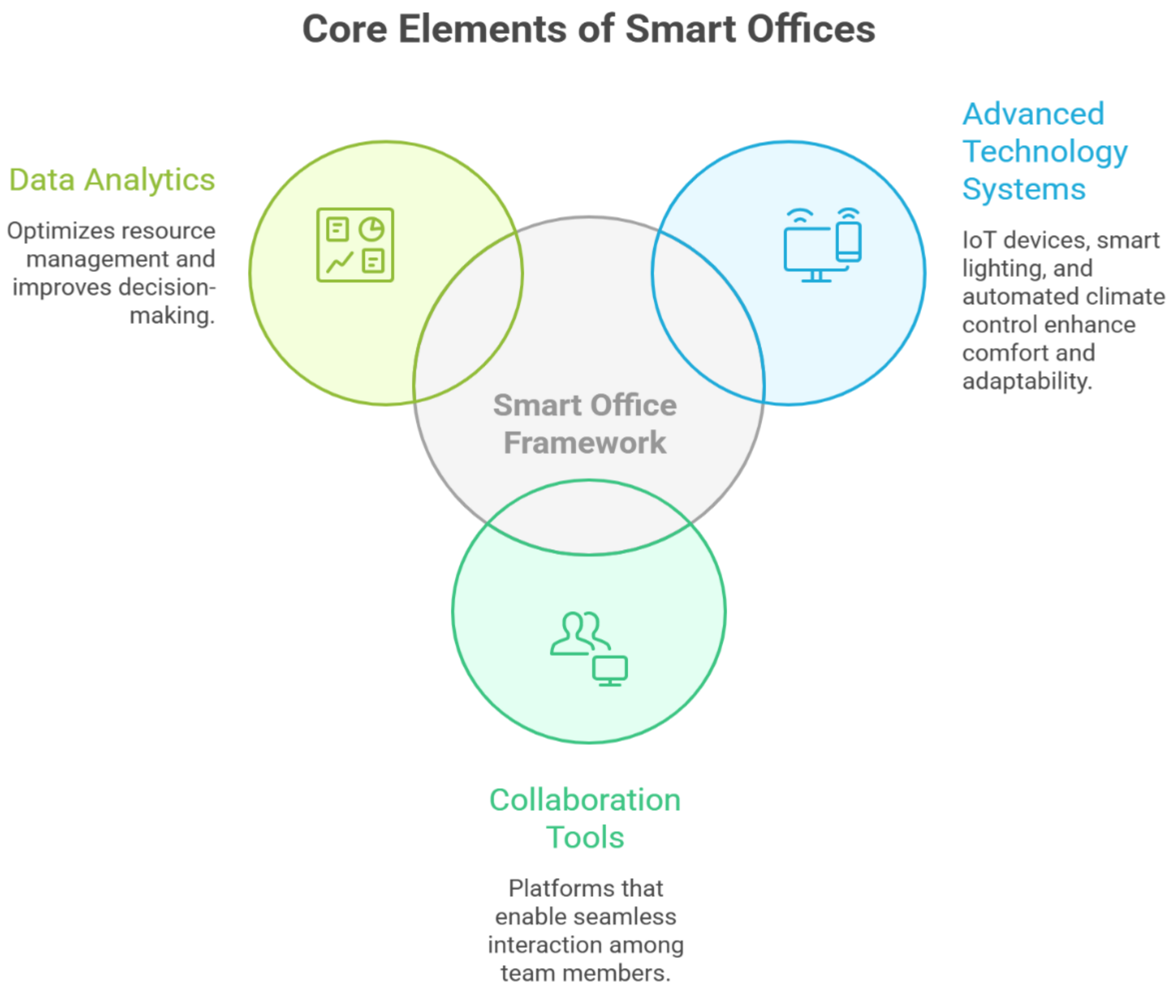

Figure 2: Framework of Smart Offices.

One critical component of this layer is the nodes' mobility using routing table information and gateways. It evaluates node power usage along anonymous channel error detection paths. This communication layer establishes communication flow. The network, also called the transmission layer, sits between perception and network layers and is referred to as this structure's brain. According to

[48], this layer performs necessary processing and assists in securing data transmission from sensors to applications and servers. This layer primarily offers gateway-based IoT convergence with wired or wireless communication networks [49]. Heterogeneous devices are linked with distinct addressing capabilities via routing tables for cooperative networks storing data on cloud servers and conducting analytics to extract information from data across various IoT platforms. This proposed framework manages the enormous Big Data volumes released by various sensor types. IoT sensor service managers effectively arrange optimal paths for all communication. Every control and management level has been integrated; real-time simulation operates within this framework and offers helpful insights into large data reception and transmission in interconnected communication device networks [50].

However, Figure 2 demonstrates successful communication. Incoming big data is examined on cloud servers and relayed to the necessary sensors following findings. Three office branches are readily visible, connected by routers. This phenomenon results from the Internet Engineering Task Force (IETF) [51] imposing IPV6 or LoWPAN protocols on various wired and wireless technologies, including fiber optic, Wi-Fi, 3G, 4G, and Public Switched Telephone Network (PSTN). To implement this framework, we created a network architecture with random positioning. This enables smart office environment creation by facilitating effective and sustainable communication between various nodes with greater throughput and reduced power consumption. This framework's top layer assists users by providing application access and customized services as needed. It manages data and services generally and transforms various applications or services differing in digital signal environments. It then provides managers with computed high-level application knowledge, including weather forecasting, office management, smart grid systems, security alarms, mobility, health or disaster monitoring, fortune, ecological and medical environment control, and transportation with overall global management [52]. It offers consumers visuals and services according to their needs and facilities for all connected end users. The entire process will be implemented to build real-time intelligent offices providing vital sensor, power, and network throughput information.

3.1 Contiki Simulation

Contiki (Instant Contiki 2.7) is an operating system used for real-time data collection and processing. A. Dunker investigated this existential approach to intelligent environments, and we built a smart office topology with numerous nodes (Motes in Contiki) to perform the necessary real-time simulation. Contiki is an open-source operating system offering various applications to simulate network environments and guarantee benefits, including data extraction, storage, collection, and transmission via communication networks [52]. It provides low-cost, low-power massive data collection through small device interconnection. Specified simulation and outcomes were achieved using one emulator, Cooja. Multiple sensors generate enormous big data volumes transmitted from our current network in real-time to servers. Additionally, as illustrated in Figure 3, Cloud servers effectively deliver appropriate analysis, called knowledge discovery to several nodes simultaneously based on incoming data. Sensors produce significant data volumes sent to cloud server gateways [52]. Every node activated LED (Light Emitting Diode) lights to transfer information across devices. Multiple windows in Figure 3 display corresponding simulation results of intelligent workplaces.

First, as visible in the window's upper left corner, the network structure connects multiple sensor motes collectively. Second, the following window provides simulation control buttons including start, pause, stop, and reload, along with total duration and speed [5]. The following box offers recording significant measurements for future reference. Third, the purple-backed window displays each mote or node output with unique IDs assigned based on programming-based classification. We used the IPv6 protocol with low-power Personal Area Network (6LowPAN) to construct an intelligent environment topology. To obtain Pcap files for transmitted network examination, select that menu option. All communication information between nodes, including protocols used for intermediary communication, is available in the radio message pane. Additionally, because IPv6 Internet Control Message Protocol (ICMP) is used, all radio messages provide complete payload data in bytes [15]. To display more radio duty cycles, power trackers of simulated individual transmission (ITX) and individual receiving (IRX), along with radio services, are displayed in the window's right bottom corner and in Table 2. The

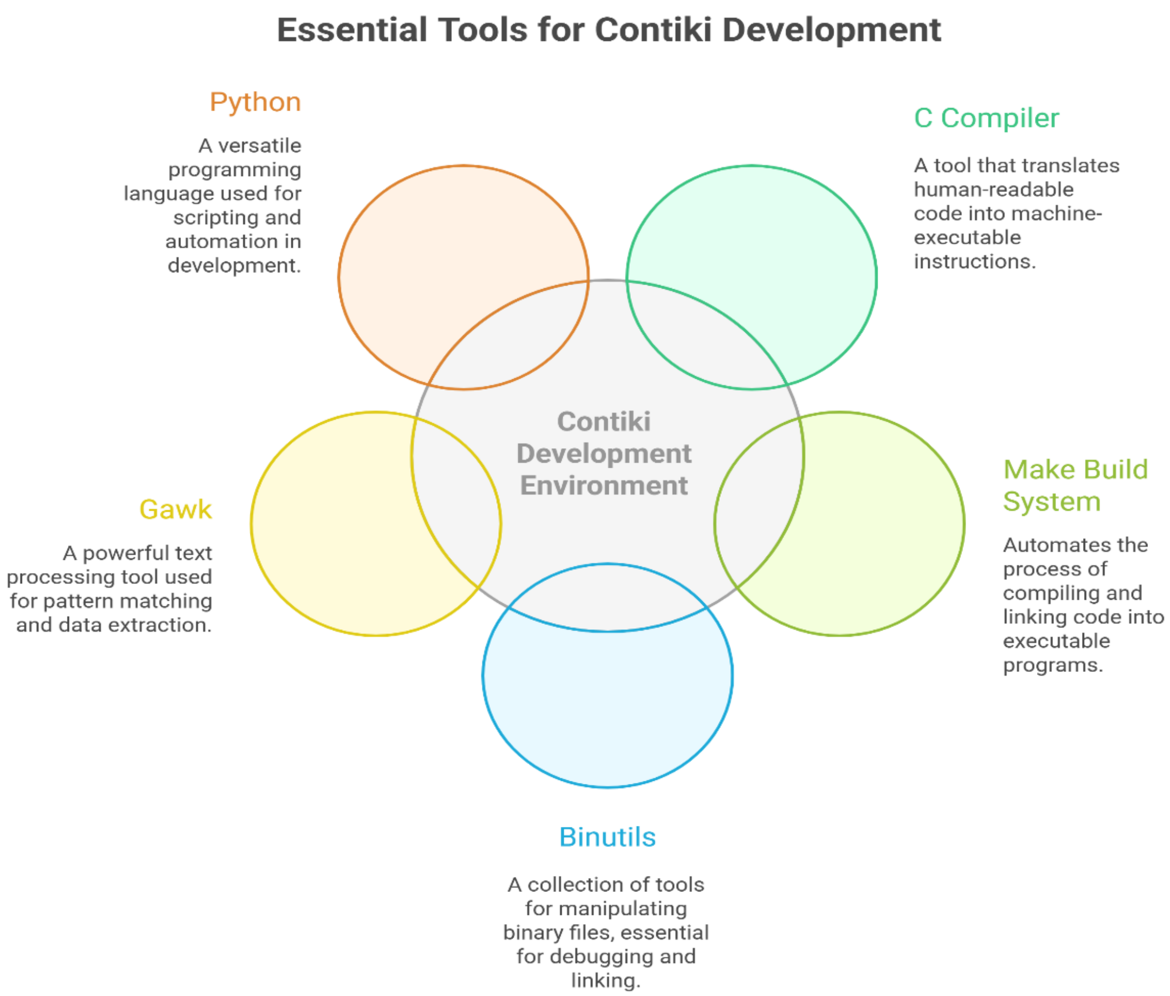

Figure 3: Simulation through Cooja Emulator of Contiki OS.

transmitted data's overall heap and stack flow are displayed in the stack pane. This Cooja emulation tool calculates percentages for each mote individually and collectively, including average percentages. Table 2 contains all simulation measurements plus designated transmission and receiving percentages for each node. We selected sky-type motes for network simulation, offering 8 MHz MSP430 micro-controllers with 48 KB flash memory and 10 KB RAM. These motes feature additional capabilities,s including network transceivers with sensors operating wirelessly and providing advantages such as 2.4GHz, 250 Kbps, and IEEE 802.15.4 Chipcon for temperature, light, and humidity measurements, battery indicators, and sensor power control. Optional 6-pin SMA antenna expansion is available [35].

By inputting border router IP addresses into browsers (Firefox), as indicated on Figure 3's right side, Contiki OS applications provide router and neighbor information for communication protocols. It provides information from other sensors, such as temperature (240C) and light (248), when IPv6 addresses of any device are entered into browser search bars [33]. Light sensors use illuminance (LUX) measuring units to determine relative distance (Onasch and Spero 2018). The last window with various colored lines displays all node chronology, and Serial Socket windows provide server-side connections with byte numbers communicated over networks. 6LowPAN was selected because it enables radio frequency communication with low-powered IPv6 versions at physical layers [33]. We included border-router programs with sky motes to ensure necessary outcomes. We collected and accessed most recent sensor-generated data using sky-websense.c applications. Integrated web servers power this real-time application. Tunslip6 utility tools connect routers across networks to external worlds using Cooja. All

Table 2: Power Traces of each mote at different positions

Network's Mote	Radio Service(%)	Radio Transmission (%)	Radio Receiving (%)
Sky 1	99.98%	0.05%	0.10%
Sky 2	0.88%	0.14%	0.00%
Sky 3	0.72%	0.02%	0.00%
Sky 4	0.74%	0.02%	0.01%
Sky 5	0.73%	0.02%	0.00%
Sky 6	0.74%	0.03%	0.01%
Sky 7	0.73%	0.02%	0.00%
Average	**14.02%**	**0.05%**	**0.03%**

windows began receiving the necessary data once the simulation was launched. Power consumption analysis facilitates easy observation of communication network efficiency [13].

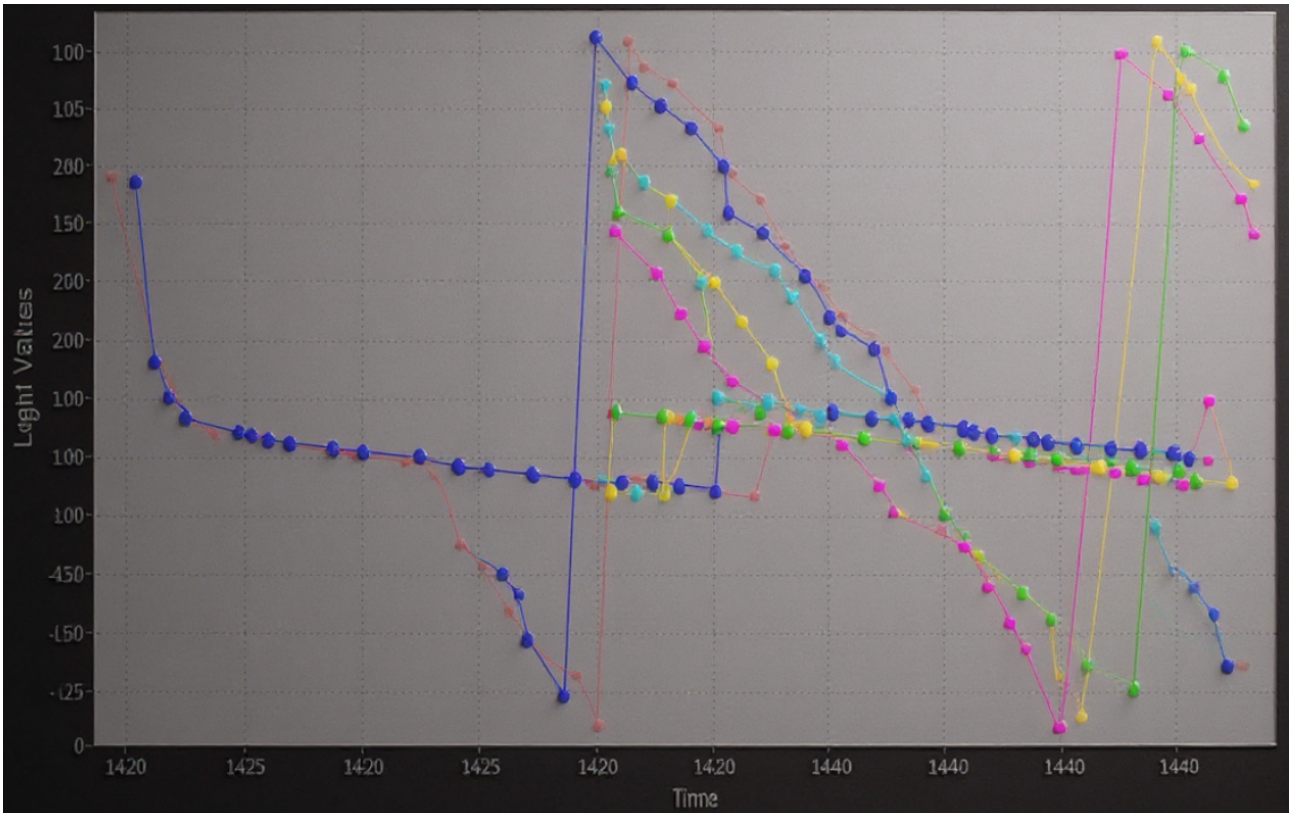

Figure 4: Result of Light and Battery Voltage.

4 Results and Analysis

The simulation produced expected efficient transmission outcomes. Our designed topology began operating over web servers once we pressed the start buttons, and all network motes (sensors) began generating real-time big data. This data travels over cloud web servers in Cooja emulators built on Contiki. Experimental outcomes provide mote ping information. Calculated outcomes divide into two categories: power measurements and sensor measurements concerning intelligent network connectivity. Results corresponding to these categories are discussed below.

4.1 Sensor Measurements

As shown in Figure 4, the simulation distributes sensors' real-time data over networked integrated systems within predetermined "Time" and "Celsius." First, we have average temperatures for every node at 615.9 degrees Celsius at 100% humidity. Battery indicators are 1 for every low-latency node. We have results for light and battery voltages used by sensors during communication. Each sensor has attached LEDs blinking when receiving transmitted data; fluctuating light data is exhibited concerning time. Battery consumption over voltage ranges between 0.00 and 0.50, indicating very low battery voltage usage for each node. Every node is represented by colors, and overall graphical shapes show back-and-forth transmission fluctuations.

$$TTX = TX1 = TX2 = TX3 = TX4 = TX5 = TX6 = TX7 \tag{1}$$

In Equation 1, TTX represents Total Temperature Transmission, and TI is node 1's temperature. This temperature is identical for all nodes when viewed collectively to determine average temperatures for all motes.

$$TBI = BI1 = BI2 = BI3 = BI4 = BI5 = BI6 = BI7 \tag{2}$$

In our given real-time simulation situation, TBI defines Total Battery Indication as in Equations 2 - 5, which is identical for every node. B1 denotes node 1's battery.

$$TPX = TPR + TPL \tag{3}$$

$$TPX = 1244 + 0 = 1244 \tag{4}$$

Total packets transmitted (TPX) equals total packets received plus total packets lost along communication networks. Equation 5indicates that the Packet Delivery Ratio (PDR) is 100

$$PDR(\%) = TotalReceivedPackets/TotalTransmittedPackets*100(4)PDR = 1244/1244*100 = 100 \tag{5}$$

4.2 Power Analysis

Several methods accomplish overall power analysis. Power history graphs provide comprehensive power usage scenarios for all nodes based on power consumption measured in megawatts. It illustrates reduced overall usage compared to slower systems. Various histograms demonstrate power utilization by different sensors [11], including immediate power usage and average power consumption with each node's radio duty cycle. Instantaneous and average power consumption sections illustrate overall power usage by multiple elements. Yellow color represents radio transmission, green represents radio listening, blue represents Control Processing Unit (CPU), and red represents Longest Prefix Match (LPM). LPM, or low power consumption algorithms, allows IP address connections to the routing tables [18]. In typical radio duty cycles, blue portions represent average message transmission while red portions display ping information from nodes listening to messages. We offered real-time simulated comparisons of two IoT environment-based topologies: the proposed system (topology indicated above) and a basic topology representing typical systems. The typical system operates under the User Datagram Protocol specifically and has seven nodes [14]. Additionally, the two systems' protocols differ, reflected in the results. Several protocols were employed to quantify relative differences, indicating 6LowPAN outperforms conventional systems in performance. Relative differences in networked node throughput and energy usage are displayed in this comparison. The period is identical for both topologies; total packets sent and received, plus packet loss are easily visible. Results show our proposed system offers higher network transmission throughput concerning megabytes (MB) sensor data sizes, meaning sensors communicate more effectively than typical systems, where throughput is comparatively low. Subsequently, energy consumption comparisons between the usual and proposed systems are presented for each node. It shows that compared to conventional systems, all proposed system nodes' energy consumption is comparatively low. When our simulation ends, all sensor network communication is

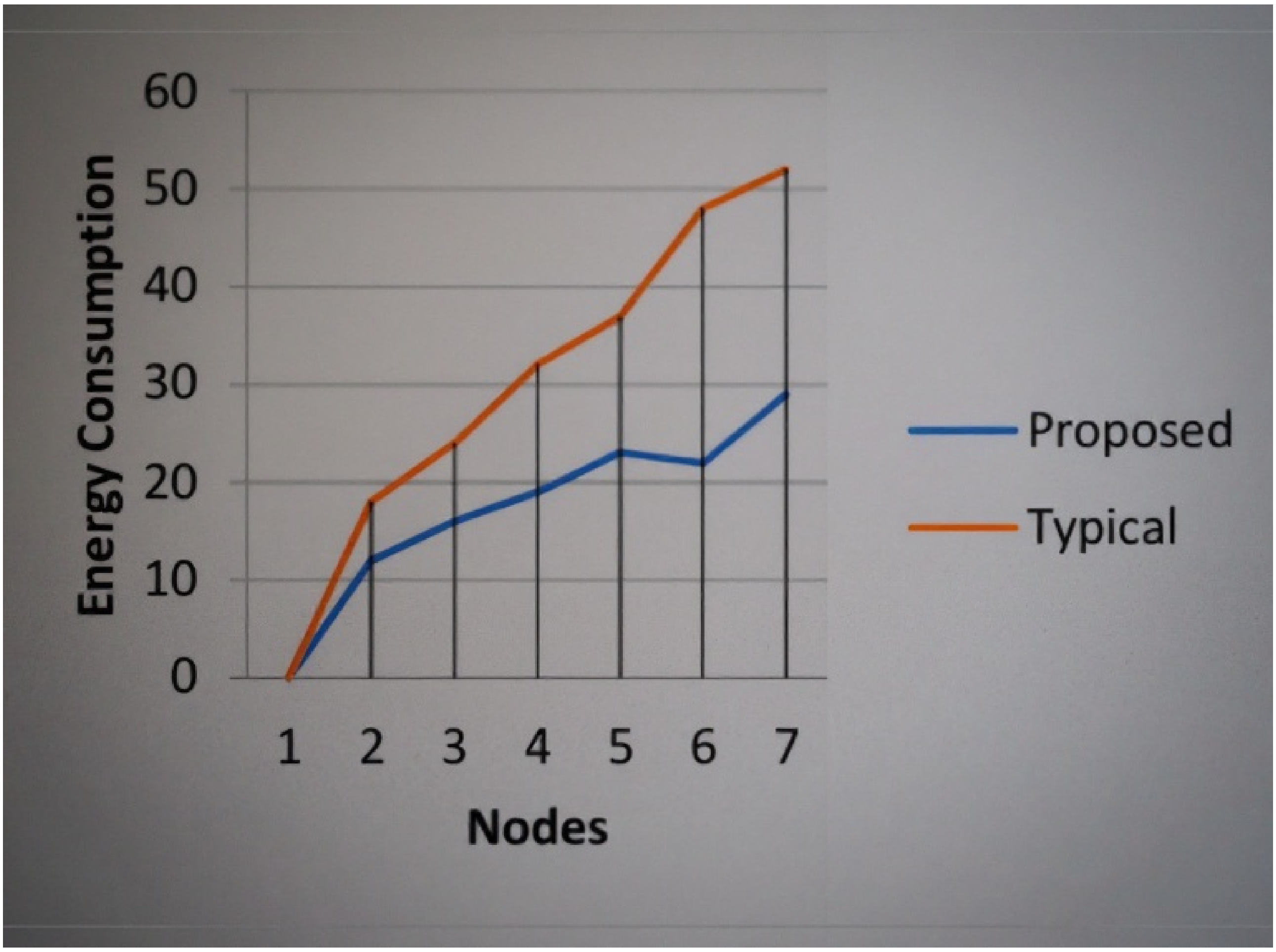

Figure 5: Energy Consumption at each Node.

preserved in Contiki OS composite files containing sent packets with ".pcap" extensions for packet capture. Wireshark programs can open and view these files, displaying network traffic metadata. The selected line in Figure 5 contains all protocol details, including frame size, standard, payload, time, and connection duration. Using various Wireshark tools, we can examine traffic for sensor network control management using this information.

4.3 Comparative Evaluation

Different intelligent environment topologies and architectures were examined based on real-time implementation in earlier research. As Table 3 illustrates, we differentiated earlier research to offer a comparative analysis of the reviewed literature with their unique methodologies. Authors of [43] provided localized frameworks for smart home data processing that are effective. Creating localized sensors can effectively represent the surrounding interdependencies of linked sensors. This framework offers optimum bandwidth power consumption forecasts based on information. Using historical communication patterns, it provides real-time defect detection and tolerance for sensors in IoT-based smart homes. This real-time connection eliminates redundancies and provides information about usage patterns and power consumption. To understand security measures, writers of [43] addressed massive data management and collection problems for IoT environments using cloud computing. To efficiently deploy smart cities through IoT devices and real-world user interfaces such as RFIDs and smartphones, authors addressed convergent domains of IoT and Cloud Computing [42]. An IoT-based cloud computing framework is suggested. Smart buildings are designed and implemented using intelligent and adaptable automated controllers [11]. According to compliance, this proposed solution improves user experience by increasing energy efficiency, comfort, and safety. It offers fast plug-and-play installation situations for automated smart building applications. Authors of [34] discussed location-aware interior

Table 3: Comparative analysis of Smart Big IoT

References	Communication Protocol	Observational Environment	Architecture
[15]	-	Localized	✓
[42]	COAP	Localized	✓
[28]	ZigBee	Localized & Generalized	✓
[11]	AIBSBAC	Localized & Generalized	✓
[10]	BTLE	Localized	✓
[34]	SFP	Localized	✓
[43]	ZigBee	Generalized	✓

architecture to improve visitor experiences. The system's design offers cultural materials to verify wearable device image recognition and localization capabilities. To publish environmental events on social networks responding to user demand, this proposed work archives multimedia materials on cloud servers.

Singularity architecture is proposed in [52] to prototype science fiction-style scenarios investigating biological development behavior. Parametric digital manufacturing and modern technologies are combined with intelligent building design using morphogenetic methods. A morphogenetic framework is suggested to account for the design team's debate implications. In [43], urban planning is covered concerning big data analysis in smart cities. Hadoop frameworks are suggested to handle four smart city data collection stages. MapReduce has been integrated with Hadoop for data management [51]. Based on Table 3, significant numbers of previously mentioned articles offer relevant work addressing Quality of Services (QoS) issues. Similarly, most writers discussed the effectiveness of smart monitoring in both localized and broader environments. Only two papers addressed security issues, while five contained transmission speed issue [43]. Through various communication protocol types, we can see that relevant prior research work has been carefully evaluated in this publication. This leads to the conclusion that while Correspondence Protocol is a typical issue, each system type's precise goals vary [43]. In conclusion, we suggest a new topology aligned with smart office frameworks. These addresses improved issues, including efficiency, low power consumption, big data management, increased throughput, low latency, and high transmission speed compared to typical systems. This real-time smart office implementation offers deployment projections for non-developing nations like Pakistan. Sensor big data is effectively collected and processed while maintaining minimal energy consumption [43]. As seen from the aforementioned literature, the protocol known as 6LowPAN (Low Power Wireless Personal Area Network) of IPv6 has been used in our real-time office application. While currently published literature uses various techniques for power and efficiency estimation in different applications, our approach utilizes Contiki OS [13].

5 Conclusion

Managing linked nodes effectively and efficiently has become more challenging due to big data. To combine their features and provide better solutions, we surveyed the most promising communication technologies, including sensors, cloud computing, big data, and IoT. Following IoT tiers, we offered a unique architecture for managing sensors in smart office installations. We demonstrated that our proposed architecture can facilitate effective network communication by building efficient sensor networks using simulation findings described above, which correspond to typical systems. A list of requirements outlining their requirements for office real-time implementation has been provided. We integrated IoT into interconnected sensor networks as part of real-time communication systems. It then effectively collects and communicates temperature, humidity, light, and movement data useful for smart office management. Users can access and manage data following distant networks to take necessary action when needed. For example, if remote users notice movement in workplaces after business hours, they can address it by taking appropriate action. Comparative analysis is carried out by carefully reading literature reviews, and we integrated smart office environments into real-time simulation using Contiki

OS's Cooja emulator to collect and transmit data efficiently using wireless technology. Data analysis, which we compared with typical systems, validates the network's successful efficiency. With reduced energy usage, our system offers improved sensor data collection and administration efficiency. To construct intelligent environments, we plan to explore various machine-learning techniques combined with security algorithms in our future work. We will compare various implementation solutions for sensor data predictability. We will evaluate various protocols' effectiveness to assess their relative power consumption, sustainability, and efficiency using different sensor characteristics. We will use several machine learning algorithms to perform analytics on sensor-collected data. We will attempt to build effective, safe, and scalable networks using various technologies.

Supplementary Materials

All relevant data is within the manuscript and its supporting information files.

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Data Availability Statement

Data sharing does not apply to this article as no new data were created or analyzed in this study.

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Conflicts of Interest

The authors declare no conflict of interest.

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