MULTIPURPOSE LAMP-POST IN URBAN PLANNING AND DESIGN

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ABSTRACT

The quest for sustainable urban development has led to the conceptualization of smart cities that intertwine innovative technologies with infrastructure to enhance efficiency, sustainability, and quality of urban living. This paper presents a comprehensive study on the design and implementation of an annulus-shaped lamppost that epitomizes this integration, utilizing 6LoWPAN technology for intelligent street lighting in the context of Dhaka, a rapidly urbanizing metropolis. The lamppost not only provides advanced lighting solutions but also harnesses solar energy and facilitates groundwater recharge, addressing two critical environmental challenges: energy conservation and water resource management.Central to our study is the application of 6LoWPAN, enabling seamless communication within the smart urban network, thereby overcoming the prevalent issue of 'information islands'. The lamppost's design—incorporating solar panels and a rainwater harvesting system—presents a multifunctional approach to urban infrastructure. The research delves into the theoretical calculations of daily energy collection and the empirical proof of concept for rainwater management.The methodology employs software tools like Wireshark for data packet analysis, revealing the efficacy of UDP in the 6LoWPAN nodes' communication process. The findings indicate a successful integration of environmental sustainability into the smart city framework, showcasing the potential of such innovations in paving the way for more connected and sustainable urban environments. This study serves as a model for future smart city initiatives, highlighting the transformative impact of merging ecological design with technological advancement in urban settings.

Keywords: Lamp-post, sustainable design, solar energy, rainwater harvesting, groundwater recharge.

1. INTRODUCTION

As the dawn of the 21st century brings unprecedented urban growth, cities worldwide face the dual challenge of ensuring environmental sustainability while improving the quality of life for their inhabitants. The concept of smart cities has emerged as a revolutionary paradigm, offering a synthesis of technology and infrastructure to address these challenges. This paper examines the implementation of an innovative, annulus-shaped lamppost in Dhaka—a city emblematic of rapid urbanization and the pressing need for sustainable infrastructure. This lamppost represents the confluence of intelligent design and environmental stewardship through its integration of 6LoWPAN technology, solar energy harnessing, and groundwater recharge capabilities.The smart city vision aspires to transcend traditional urban development by embedding intelligence into the very fabric of city infrastructure. Intelligent street lighting systems are a cornerstone of this vision, given their ubiquitous presence and potential as multifunctional urban assets. The transition from isolated information islands to a cohesive network of intelligent systems is vital for the actualization of an interconnected urban ecosystem. The emerging technologies of cloud computing and big data analytics further augment this transition, promising an era of urban management characterized by seamless information exchange and real-time responsiveness.

In Dhaka, where rapid urban expansion is often accompanied by environmental strain, the integration of sustainable technologies into everyday infrastructure is not merely an aspiration but a necessity. The annulus-shaped lamppost introduced in this study is designed to function as more than a source of light; it is an active participant in the city's sustainability efforts. With solar panels strategically embedded in its canopy, the lamppost is a testament to the potential for renewable energy to power urban life. The significance of such self-sustaining systems cannot be overstated in a world grappling with the consequences of climate change and resource depletion.The lamppost's design is further complemented by its rainwater harvesting system, which not only mitigates urban flooding but also contributes to the replenishment of dwindling groundwater reserves. This feature is particularly pertinent in Dhaka, where groundwater levels have been a cause for concern. By capturing and filtering rainwater for subterranean storage, these lampposts transform passive city fixtures into proactive agents of environmental change.

Utilizing 6LoWPAN technology, the lampposts are interconnected within a wireless personal area network that supports IPv6 communication. This technology enables each lamppost to be a node within a larger network, capable of collecting, sending, and receiving data. Such connectivity is crucial for the centralized monitoring and management of urban lighting systems, allowing for adaptive lighting strategies that reduce energy consumption and enhance public safety.The practical implementation of this technology, as demonstrated in this research, involves a detailed analysis of data packets using Wireshark. This analysis provides insight into the communication efficacy between the 6LoWPAN nodes and the central controlling system, showcasing the robustness of UDP as the protocol of choice for this application. The research findings underscore the successful deployment of an intelligent street lamp network that not only illuminates urban spaces but also contributes to the city's environmental goals. Figure 1 represents a typical intelligent street lamp network system, showcasing a sophisticated integration of various components.This study aims to contribute to the body of knowledge on smart city technologies while providing practical insights into the deployment of sustainable urban infrastructure. The annulus-shaped lamppost serves as a beacon for future developments, embodying the principles of innovation, sustainability, and intelligent design that are central to the smart city ethos. Through this integration of technology and ecological design, the paper envisions a future where urban environments are not only smarter but also more attuned to the needs of both their residents and the planet.
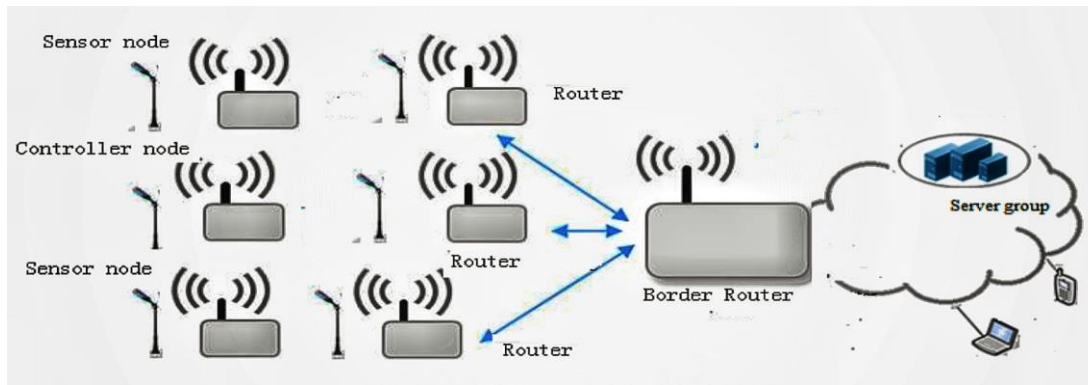
Figure 1: Typical intelligent street lamp network

2. LITERATURE REVIEW

In their 2017 study, Ricardo et al.[1] explore the possibilities of urban infrastructure. They highlight how streetlight systems are evolving into dynamic digital platforms with data integration and actuation capabilities. By upending conventional mono-functionality, this creative strategy opens the door for smart cities. Their study offers fascinating new avenues for urban growth.

The study conducted in 2021 by Hudson-Smith et al.[2] delves into the nascent domain of Urban Internet of Things (IoT) in the framework of smart cities. They draw attention to its use in gathering data at different scales, covering topics from societal to environmental. The chapter uses examples from deployments in London's Queen Elizabeth Olympic Park to illustrate the technology underlying urban IoT and its problems. Most notably, it highlights how commonplace urban features like lampposts can help advance Urban IoT. According to their research, data collection, analysis, and communication in metropolitan areas are undergoing a radical change.

In Cellary's (2013) [3] view, "smartness" is an ecosystem that works together between people and technology to provide a range of e-services that improve people's lives. This vision highlights the necessity for direct consumer income to maintain smart businesses, while also posing issues related to privacy and the economy. The article highlights the three roles that smart governance plays in promoting smart industries, protecting privacy, and bridging the public-private divide. It also discusses potential risks to trust within smart industries and governance.

In his critical evaluation of smart city concepts, Dawkins (2017) [4] highlights the limitations of urban control rooms' capacity to provide a full explanation of urban dynamics. The study compares locally tailored, subjectively informed procedures with data-driven, top-down approaches. It questions if control rooms and Mirror Worlds are the same thing, and it promotes the use of cutting-edge technologies to meet the demands and aspirations of a varied metropolitan population while establishing new digitally mediated forms of agency.

The rapid rise of London's population, which is expected to exceed 10 million by 2030 and reach nine million by 2021, is addressed in the "Smart London Plan," which was announced by GLA in 2013[5].The result of this growth is an increase in the demand for public transit, 800,000 new houses, and nearly 641,000 new employment. The plan places a strong emphasis on making the most of London's technological potential in order to boost infrastructure and services for both citizens and businesses, as well as to increase the city's functionality and support its growth. It promotes creativity among world-class scholars and businesspeople to address the obstacles posed by London's expansion, with City Hall playing a pivotal role in this undertaking.

Goodchild[6] reassesses the history of GIS in his 2018 essay, raising doubts about the choices taken in the field's formative years when computing power was limited. He imagines a different emergence of GIS in the present day, one that is based on globes, hierarchical data structures, and early spatial uncertainty resolution. According to Goodchild, there are still remnants of the 1960s computational restrictions present in modern GIS.

The historical relevance of an inventive 1916 lamppost built by the Ottawa Improvement Commission is explored by Collins (1993)[7].This concrete lamppost, which is situated along the Federal Driveway, is remarkable for both its innovative material use and its aesthetic influence on the

surroundings. As a historical site, it now symbolises the goals of urban reform in the early 20th century, which were influenced by the City Beautiful movement and its relationship to architecture and urban planning.

A remotely controlled street lighting system is one of the features of the smart city application presented by Leccese, Cagnetti, and Trinca (2014) [8].This creative system consists of ZigBee networks for local data transmission, lamp posts with electronic management cards and a central control unit run by an inexpensive Raspberry-Pi card. Additionally, a WiMAX link for remote smart grid control was successfully tested by the authors, making it a workable alternative for managing metropolitan lights.

The integration of intelligent LED streetlights into a flexible infrastructure for lighting control and a variety of smart city applications is being studied by Hassebo and Ali (2020)[9].Every smart streetlight transforms into a hub node with multiple sensors that can collect and send data in real time to the cloud. Their study evaluates the viability and measures the effectiveness of commercial 4G LTE cellular networks in terms of linking many cloud-connected smart streetlight hub nodes. These nodes manage a range of services, with a focus on strict latency and reliability requirements, including mission-critical applications like HD IP video surveillance cameras.

The critical role that communication technologies play in smart street lighting and other add-on applications inside smart cities is explored by Murat Kuzlu and Manisa Pipattanasomporn (2021)[10].Making use of the expansion of broadband connectivity and IoT devices, they highlight smart street lighting as an affordable option for urban development. In order to support a variety of smart city applications, the chapter thoroughly examines a number of communication technologies, such as Sigfox, LoRa, NB-IoT, WiMAX, and Cellular. These technologies are assessed based on data rate, latency, dependability, and security[Table.1].

Table:1 Summary of the Literature Review

Reference	Focus of Study	Techniques Used	Key Findings
Ricardo et al. (2017) [1]	Urban infrastructure	Dynamic digital platforms, data integration, actuation capabilities	Streetlight systems evolving into dynamic digital platforms, opening possibilities for smart cities and urban growth
Hudson-Smith et al. (2021) [2]	Urban Internet of Things (IoT) in smart cities	Data gathering at different scales, urban IoT technology, deployments in London's Queen Elizabeth Olympic Park	Urban IoT transforming data collection, analysis, and communication in metropolitan areas; common urban features like lampposts advancing urban IoT
Cellary (2013) [3]	"Smartness" ecosystem	Collaboration between people and technology, providing e-services, smart governance	Smart governance roles in promoting smart industries, protecting privacy, and bridging public-private divide; discussion on risks to trust within smart industries and governance
Dawkins (2017) [4]	Smart city concepts	Comparison of control rooms and Mirror Worlds, use of cutting-edge technologies	Limitations of urban control rooms in explaining urban dynamics; advocacy for cutting-edge technologies to meet diverse population needs and establish digitally mediated agency
GLA Smart London Plan	London's population	Emphasis on utilizing	Addressing challenges of

(2013) [5]	growth and smart city plan	technological potential for infrastructure, services, and city functionality	London's population growth, promoting creativity among scholars and businesspeople, City Hall's pivotal role in supporting infrastructure and services
Goodchild (2018) [6]	History of GIS	Reassessment of GIS history, imagining a different emergence in the present day	Doubts about choices in GIS formative years, imagining a present-day GIS based on globes, hierarchical data structures, and early spatial uncertainty resolution; remnants of 1960s computational restrictions in modern GIS
Collins (1993) [7]	Historical lamppost	Exploration of Ottawa Improvement Commission's 1916 lamppost, its material use, and aesthetic influence	Lamppost as a historical site symbolizing urban reform goals in the early 20th century, influenced by the City Beautiful movement and its connection to architecture and urban planning
Leccese, Cagnetti, and Trinca (2014) [8]	Smart city application	Remotely controlled street lighting system with ZigBee networks, electronic management cards, Raspberry-Pi card, WiMAX link	Features of a creative smart street lighting system, successful testing of WiMAX link for remote smart grid control, offering a workable alternative for managing metropolitan lights
Hassebo and Ali (2020) [9]	Intelligent LED streetlights	Integration into flexible infrastructure, multiple sensors, real-time data transmission to the cloud	Evaluation of viability and effectiveness of commercial 4G LTE cellular networks in linking smart streetlight hub nodes; focus on strict latency and reliability requirements, including mission-critical applications like HD IP video surveillance cameras
Murat Kuzlu and Manisa Pipattanasomporn (2021) [10]	Communication technologies in smart cities	Broadband connectivity, IoT devices, assessment of communication technologies (Sigfox, LoRa, NB-IoT, WiMAX, Cellular)	Exploration of the critical role of communication technologies in smart street lighting and other applications; smart street lighting as an affordable option for urban development; thorough examination of various communication technologies based on data rate, latency, dependability, and security

3. DESIGN OF THE MODEL

In the **[Fig-2]** depicts a schematic of an annulus-shaped lamppost that incorporates an integrated rainwater recharge well system. The upper portion of the diagram shows the lamppost with its distinctive annular design, which likely functions to capture and channel rainwater efficiently. The lamppost's broad canopy not only serves as a catchment area for rainwater but also houses solar panels, which are used to power the lamppost.Below the surface, we see a detailed cross-section of the rainwater recharge system. Rainwater collected by the lamppost's canopy is directed through a baffle, which serves to slow and regulate the flow, preventing erosion and sediment disturbance within the recharge well. The water then passes through a V-wire screen, a filtration component that likely removes larger debris before the water enters the recharge system.Beneath the V-wire screen, there is a layer of gravel which may act as a pre-filter. Following this, the water enters the main filter pit, which is filled with filter materials separated by a PVC mesh. This mesh likely ensures that different grades of filter material remain in place, each layer contributing to the purification of the rainwater by removing smaller particulates.The clean, filtered water then percolates down to a deeper layer of pea gravel, before entering the V-wire screen at the bottom of the recharge well. This final screen likely serves as a last filtration stage before the water is introduced into the subterranean water table through the bore and casing pipe. The 250 mm/350 mm diameter bore and the 140 mm/200 mm diameter casing pipe facilitate the movement of water into the underground reservoirs, replenishing groundwater supplies.The annulus-shaped lamppost depicted in the **[Fig-3]** represents a breakthrough in smart urban design, combining functionality with sustainability. The lampposts are designed with a height of approximately 8 meters and are spaced about 20 to 24 meters apart. Each lamppost is outfitted with 6 to 8 solar panels. These panels are not just ornamental additions; they are powerful energy collectors with an output ranging from 150 to 250 watt-hours per panel. This design ensures that a substantial amount of solar energy is harnessed throughout the day. The lamppost's shape is engineered to maximize rainwater capture. Water passing through the system is not only harnessed for immediate use but is also systematically filtered and directed towards subterranean reservoirs, aiding in groundwater recharge. This dual functionality of harnessing renewable energy and contributing to water conservation efforts addresses two of the most pressing environmental concerns of urban areas.Moreover, the sleek and modern design of the lamppost adds aesthetic value to the cityscape while offering a futuristic model of urban infrastructure. Its height and spacing are calculated to provide optimal light coverage, enhancing public safety and visibility after dark. The use of LED lighting technology within these lampposts further ensures energy efficiency and longevity.
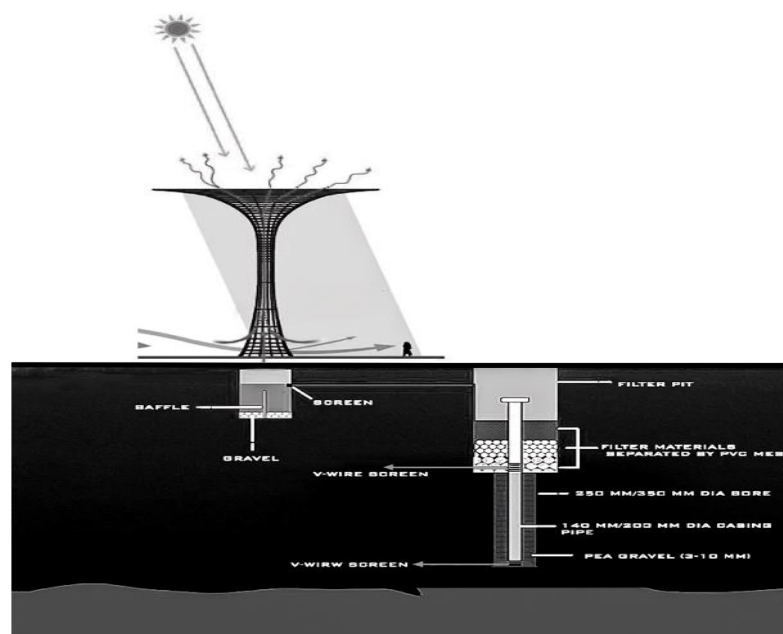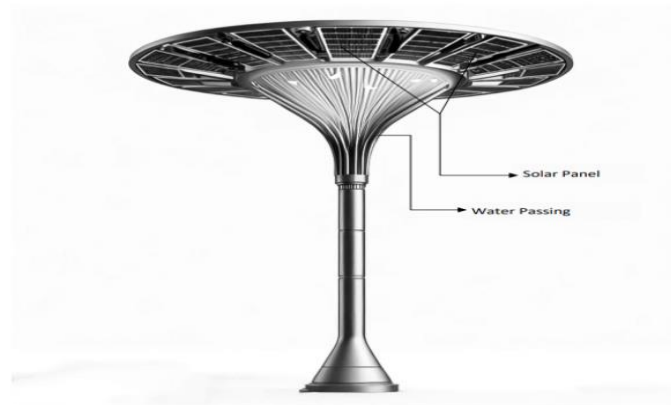
Figure 2: Rainwater recharge well

Figure 3: The annulus shaped lamppost

4. GENERAL CONCEPT OF THE 6LOWPAN SYSTEM

In the burgeoning landscape of smart urban development, the deployment of intelligent street lamp systems has emerged as a pivotal element. These systems are underpinned by advanced wireless communication technologies, which are essential in bridging the critical gap in the last 100 meters of network connectivity among street lamps. The technologies at the forefront of this innovation include ZigBee, 6LoWPAN, and WLAN, each playing a unique role in the network infrastructure.ZigBee, a technology rooted in the IEEE802.15.4 protocol standard, operates within the 2.4G open band and is lauded for its dual-directional short-range communication capabilities. Its appeal lies in attributes such as minimal power consumption, affordability, and the capacity to support a vast network with low data rate requirements and reduced delays. Initially, ZigBee was widely adopted for the final stretch of intelligent lighting networks due to these advantages. However, a critical challenge arose from the inherent limitations of ZigBee nodes, which typically lack an IP address. This posed a significant obstacle in achieving network interoperability, particularly given the prevalence of the TCP/IP protocol in modern internet infrastructure. As a result, the reliance on gateways for ZigBee networks often led to inefficiencies and complexity in system integration.In contrast, 6LoWPAN technology emerges as a more adaptable and efficient alternative for intelligent street lamp networks. While sharing some operational similarities with ZigBee, 6LoWPAN distinguishes itself in several key aspects, particularly in network construction and gateway utilization. Significantly, 6LoWPAN operates as an application-independent IP gateway, in contrast to the serial port gateway typical of ZigBee systems. This distinction becomes particularly advantageous when considering network interconnectivity and service systems. The intrinsic TCP/IP architecture of 6LoWPAN enables each node within the network to be individually identifiable and accessible, which is crucial for the functionality of intelligent street lamps.At present, smart city systems often operate on IPv4 networks, but a shift towards IPv6 is on the horizon. The intelligent street lamp network is structured in a layered manner, reflecting a typical Internet of Things (IoT) architecture. This structure is divided into the physical layer, encompassing diverse sensor nodes and actuators; the network layer, which utilizes 6LoWPAN to form a network and transitions to IPv4 for short-distance communications; and the application layer, handling essential services such as data processing, storage, and management. This multi-layered approach not only ensures efficient operation but also facilitates adaptability and scalability, crucial for the dynamic environment of urban infrastructure.The convergence of these technologies and structural approaches marks a significant step in the evolution of smart urban planning. By harnessing the potential of 6LoWPAN and intelligently integrating it within the street lamp network, cities like Dhaka are paving the way for more connected, efficient, and responsive urban ecosystems.This schematic outlines the hardware configuration of a typical 6LoWPAN node controller, integrating a CC2538 ARM Cortex-M3 as the central processing unit. The node features a

wireless transceiver for network communication and is equipped with sensors to measure environmental variables such as temperature, humidity, brightness, and sound **[Fig-4]**.A current controller and switch controller are included for effective energy management, while a time circuit ensures synchronous operations. The design is completed with a power supply circuit and support for JTAG and USART/I2C interfaces, enabling comprehensive programming and interfacing capabilities.
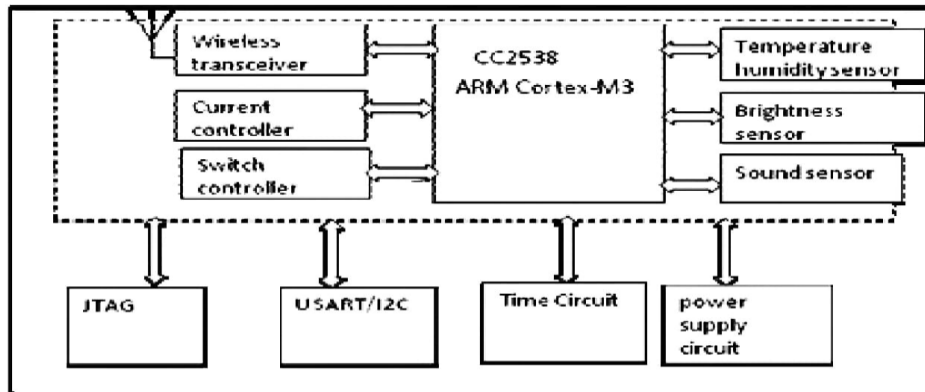

Figure 4: Typical 6LoWPAN node controller hardware

4.1 Designing a 6LoWPAN Boundary Router

The design of a 6LoWPAN boundary router plays a pivotal role in establishing a robust and efficient network infrastructure. This particular design focuses on creating a boundary router that serves as a critical junction point between various network nodes and a central server. The router is engineered to facilitate seamless communication across two primary interfaces: a wireless local area network (WLAN) or an Ethernet connection to the server, and a wireless network to interact with the network nodes.At the heart of this boundary router design lies the Texas Instruments CC2538 chip, chosen for its reliability and suitability as the main controller. This choice streamlines the design process, ensuring both stability and efficiency in router operations. The CC2538 chip is renowned for its robust performance in handling complex network tasks, making it an ideal fit for the central role it plays in this router design.One of the key requirements for the boundary router is the ability to communicate effectively with multiple nodes dispersed throughout a street network. This necessitates a substantial transmission power, which is where the CC2592 module comes into play. Integrated into the radio frequency (RF) portion of the design, the CC2592 module significantly enhances the transmission power. This enhancement is crucial for maintaining strong and stable connections over longer distances or in environments with potential signal interference.For the Ethernet interface, the ENC28J60 chip is utilized as the main component. This chip is specifically chosen for its compatibility and performance in Ethernet-based communications. Its integration into the boundary router design ensures that the router can reliably handle Ethernet traffic, providing a stable and high-speed connection to the server.In the **[Fig.5]** illustrates the communication process between a PC and a 6LoWPAN node. An IPv4 host interfaces with a border router through an IPv4/IPv6 adapter, which facilitates the translation and routing of packets between IPv4 and IPv6 networks. The border router then communicates with a 6LoWPAN node, employing a second IPv4/IPv6 adapter within the node to maintain the integrity of data exchange. The process centers on a data forwarding mechanism that ensures the accurate and efficient transfer of information between the disparate IP protocol versions.
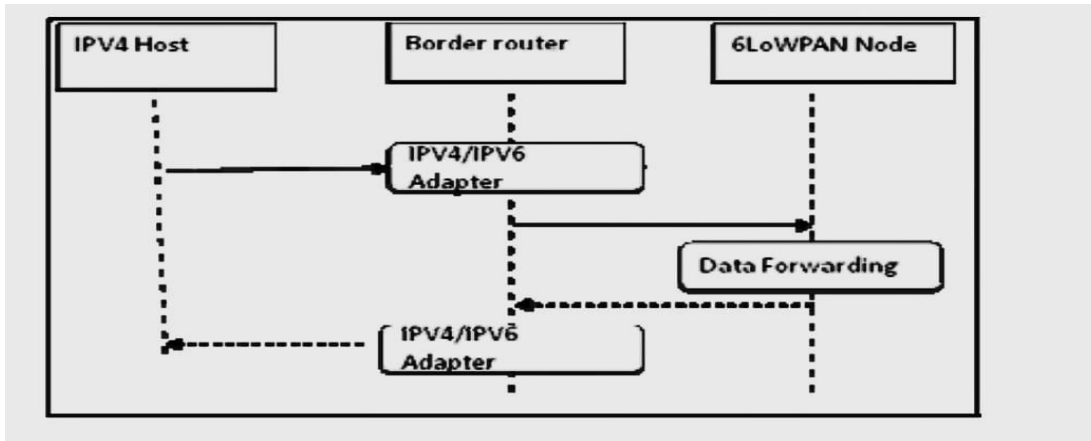
Figure 5: Communication process between PC and node

4.2 Development Environment

The development environment for our research encompasses not only the creation of 6LoWPAN application software but also integrates the environmental sustainability aspect through the inclusion of rainwater recharge capabilities in the smart lamppost design. This multifaceted approach is supported by the Contiki operating system, which acts as the foundational platform for our project.Contiki, renowned for its adaptability as an open-source and multitasking operating system, is particularly tailored for efficient programming in C. This environment is well-suited for our project as it supports the implementation of applications that not only communicate via the 6LoWPAN protocol but also interact with the physical environment to support rainwater harvesting.Embedded within Contiki are two protocol stacks, uIP and Rime, which facilitate versatile network communication. The uIP stack, compatible with both IPv4 and IPv6, ensures our applications can seamlessly connect to the internet, an essential feature for monitoring and managing the rainwater recharge system remotely. Rime offers alternative networking protocols, allowing our applications to be customized for specific environmental data collection and control tasks associated with the rainwater recharge process.To simulate and validate these complex interactions between software and environmental systems, we utilize Cooja, Contiki's advanced simulation tool. Cooja enables us to model the behavior of our networked lampposts under various weather conditions, ensuring that the software reliably performs its dual role of communication and environmental management.The development workflow is streamlined through the availability of Contiki's source files, easily downloadable from its official site. Further enhancing our development environment, Instant Contiki provides a ready-to-use platform based on Ubuntu. By deploying it on VMware, we expedite our setup process, thereby allocating more resources to the intricate task of integrating the rainwater recharge mechanism within our intelligent street lamp network nodes.Incorporating rainwater recharge into the development environment is essential, as it aligns with our project's goal of creating not only an intelligent lighting network but also an eco-friendly urban infrastructure that contributes to groundwater replenishment. Through this approach, our research aims to set a precedent for smart city initiatives that converge technological innovation with environmental conservation.

4.3 Realization of Network Communication Function

In this section of the research paper, we delve into the implementation of network communication functionality, particularly focusing on the interaction between PC systems and 6LoWPAN nodes. This interaction is crucial in establishing seamless communication across different network protocols, namely IPv4 and IPv6.The communication process is initiated when an IPv4 host needs to send commands to a 6LoWPAN node. Due to the inherent protocol differences, these commands cannot be directly understood by the 6LoWPAN node. To bridge this gap, the information from the IPv4 host is first routed to an IPv4/IPv6 adapter, often located at a border router. This border router plays a pivotal role in protocol transformation, converting IPv4 messages into a format recognizable by the 6LoWPAN node.Similarly, data collected by the 6LoWPAN node needs to undergo a reverse

transformation when being sent back to the IPv4 network. This transformation is facilitated through an IPv6/IPv4 adapter, ensuring the data is compatible with the receiving network's protocol.In the **[Fig.6]** provided C code defines a function that converts an IPv4-mapped IPv6 address to its IPv4 equivalent using standard network programming functions.To address the compatibility with the prevalent IPv4 networks, an adapter for IPv6 to IPv4 conversion is integrated within the routing node. This conversion process in Contiki involves addressing the disparity in address lengths between IPv4 (32 bits) and IPv6 (128 bits). In Contiki, this is managed by setting the first 10 bits of the IPv6 address to zero and the subsequent two bits to one. The IPv4 address is then embedded into the last 32 bits of the IPv6 address. This method enables the seamless translation of IPv4 addresses to IPv6, facilitating communication from the PC to the 6LoWPAN border router.For validating the legitimacy of an IPv6 address, the system checks if the first 10 bytes are zeros and the 11th and 12th bytes are ones. If this condition is met, the last 32 bits are extracted and used as the IPv4 address, enabling the transmission of data from the IPv6 network to the IPv4 network.The realization of the node network within this framework relies on the 6LoWPAN neighbor discovery protocol. This is achieved by invoking the uip_ds6 file within the IPv6 folder of the Contiki system, which facilitates node registration to the network.Upon successful registration of a 6LoWPAN node to the border router, a tangible indication of the network's operational status is provided through the node controller. This is typically represented by four LED indicator lights on the node. When all LEDs are fully illuminated, it signifies a successful network connection, indicating that communication between the PC and the 6LoWPAN node is effectively established. This visual feedback is an essential aspect, as it provides immediate and clear confirmation of network functionality and status.

```c
#include <stdio.h>
#include <string.h>
#include <arpa/inet.h>

int ipv6_to_ipv4(const char *ipv6addr_str, char *ipv4addr_str) {
    struct in6_addr ipv6addr;
    struct in_addr ipv4addr;

    // Convert the string representation of the IPv6 address to a struct
    if (inet_pton(AF_INET6, ipv6addr_str, &ipv6addr) != 1) {
        fprintf(stderr, "Invalid IPv6 address.\n");
        return 0;
    }

    // Check if the IPv6 address is a mapped IPv4 address
    if (IN6_IS_ADDR_V4MAPPED(&ipv6addr)) {
        // Extract the IPv4 part out of the IPv6 address
        memcpy(&ipv4addr, &ipv6addr.s6_addr[12], sizeof(ipv4addr));
        // Convert the binary IPv4 address to a string
        if (inet_ntop(AF_INET, &ipv4addr, ipv4addr_str, INET_ADDRSTRLEN) == NULL) {
            fprintf(stderr, "Invalid IPv4 address extracted.\n");
            return 0;
        }
        return 1; // Success
    } else {
        fprintf(stderr, "The provided IPv6 address is not an IPv4-mapped address.\n");
        return 0;
    }
}

int main() {
    const char *ipv6addr_str = "::ffff:192.0.2.128"; // Example IPv6-mapped IPv4 address
    char ipv4addr_str[INET_ADDRSTRLEN]; // Buffer to store the resulting IPv4 address string

    if (ipv6_to_ipv4(ipv6addr_str, ipv4addr_str)) {
        printf("IPv4 address: %s\n", ipv4addr_str);
    } else {
        printf("Failed to convert IPv6 address to IPv4.\n");
    }

    return 0;
}
```

Figure 6: IPV4 and IPV6 address translation code

4.4 Data Packet Analysis

In the research paper, we examine the data exchange process between 6LoWPAN nodes and a PC, focusing on the analysis of data packets. To conduct this analysis, we employ Wireshark, a widely recognized software tool for network protocol analysis. This approach allows for an in-depth examination of the communication process and the underlying protocols in use.During the analysis, it becomes evident that the 6LoWPAN nodes utilize the User Datagram Protocol (UDP) at the transport layer for sending data packets. UDP is chosen for its efficiency and simplicity, which is particularly

advantageous in the context of 6LoWPAN where resources such as bandwidth and processing power are limited.

5. CONCLUSION AND FUTURE WORK

The exploration of the annulus-shaped lamppost in Dhaka as a cornerstone of smart city development encapsulates a forward-thinking approach to urban sustainability and technological integration. This study has demonstrated that the amalgamation of 6LoWPAN technology with renewable energy sources and water conservation methods is not only viable but also essential in the face of rapid urbanization and environmental challenges. The successful implementation of these lampposts in Dhaka offers a blueprint for future urban development, emphasizing the crucial role of innovative infrastructure in achieving sustainable urban ecosystems.Central to the success of this project is the seamless integration of technology with ecological design. The use of 6LoWPAN technology ensures robust and efficient communication within the urban network, transforming traditional street lighting into dynamic, interconnected systems. This innovation is pivotal in transitioning from isolated infrastructural elements to a cohesive, intelligent urban fabric. The application of solar energy and rainwater harvesting further elevates the lampposts from mere lighting fixtures to proactive agents of environmental stewardship, addressing the pressing global issues of energy conservation and water resource management.Building upon the foundation of the annulus-shaped lamppost and its integration into the smart city framework, there are several promising avenues for future research and development. One notable area of exploration is the utilization of the sensors embedded within these lampposts to gather valuable data about the urban environment. These sensors can provide real-time information on various aspects of the city, which can be harnessed for the betterment of urban living.For instance, the lampposts equipped with environmental sensors can monitor air quality, temperature, humidity, and noise levels. This data can be used to create an accurate and up-to-date environmental profile of the city. Additionally, by incorporating traffic flow sensors, the lampposts can contribute to comprehensive traffic management solutions. For example, they can detect traffic congestion, vehicle counts, and even road conditions during adverse weather. This wealth of data can be harnessed to develop intelligent traffic management systems that optimize routes, reduce congestion, and enhance overall transportation efficiency.

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