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Abstract

The rapid growth of Internet of Things (IoT) technologies has significantly transformed urban healthcare systems, enabling continuous health monitoring, data aggregation, and real-time decision-making. the integration of mobile and fixed IoT devices in urban health networks introduces substantial challenges related to energy consumption, network congestion, and device longevity. This chapter explores the optimization of energy-efficient routing protocols in IoT systems, focusing on their application in urban health environments. Emphasis was placed on adaptive energy management techniques, including duty cycling, sleep modes, and machine learning-based routing strategies, aimed at minimizing power consumption while ensuring reliable communication. The chapter highlights the role of distributed energy management protocols, energy-aware communication strategies, and the potential of machine learning in optimizing energy consumption across multi-hop communication networks. Case studies and experimental results demonstrate the practical applications of these approaches in enhancing the efficiency and scalability of urban health IoT systems. The integration of energy-efficient routing protocols with mobile health devices was examined in detail, emphasizing the need for context-aware solutions that adapt to dynamic urban settings. Ultimately, this work provides a comprehensive framework for the design and implementation of sustainable, energy-efficient IoT systems that support effective urban health monitoring and improve healthcare outcomes.

Keywords: Energy-Efficient Routing, IoT Systems, Urban Health Networks, Machine Learning, Adaptive Energy Management, Mobile Health Devices.

Introduction

The integration of Internet of Things (IoT) technologies into urban healthcare systems has revolutionized the way health data was collected, transmitted, and processed [1]. IoT-based health devices, such as wearable sensors, mobile health applications, and remote diagnostic tools, are increasingly deployed to enable real-time monitoring of individuals' health status in urban environments [2]. These devices allow for continuous data collection on parameters such as heart rate, blood pressure, and glucose levels, which contribute to a more personalized and efficient healthcare approach [3]. the rapid expansion of IoT devices in urban health systems introduces several technical challenges, particularly regarding energy consumption, device longevity, and network reliability [4]. As the majority of these IoT devices rely on battery power, optimizing energy usage was crucial to extend their operational lifetime while maintaining the effectiveness of health monitoring tasks [5].

Energy management becomes even more critical in mobile health IoT systems, where devices are subjected to dynamic environmental conditions and mobility patterns [6]. Urban environments, characterized by their dense infrastructure, traffic, and varying network coverage, create a challenging context for energy-efficient communication [7]. IoT devices often experience fluctuating signal strength, congestion, and frequent handoffs between network nodes [8]. In this dynamic environment, ensuring that devices remain operational while minimizing power consumption requires adaptive strategies [9]. These strategies must account for factors such as network congestion, device movement, and available energy resources to make real-time adjustments to power consumption and communication protocols [10]. In such settings, traditional, static routing protocols are insufficient, and more dynamic, energy-efficient solutions are required to maintain a balance between performance and power consumption [11].

One key approach to addressing energy efficiency in urban health IoT systems was the development of adaptive energy management protocols [12]. These protocols adjust the operational behavior of devices based on real-time information, including battery status, signal quality, and communication requirements [13]. Adaptive energy management mechanisms, such as duty cycling and sleep modes, play an essential role in reducing energy consumption [14]. Duty cycling allows devices to alternate between active and idle states, ensuring that power was only consumed when data transmission was necessary [15]. Similarly, sleep modes enable devices to enter low-power states during periods of inactivity, conserving battery life without compromising the ability to transmit critical health data when required. By dynamically adjusting the operating parameters of devices based on real-time conditions, these protocols enable a significant reduction in energy consumption, thus extending the operational lifespan of devices deployed in urban health IoT systems [16].