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Assessment of the Promotional Effects of New Energy Fitness Equipment on Sports Economics and Management

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ABSTRACT

The Internet of Things (IoT) technology offers significant advancements in fitness trackers and AI-driven health management systems and presents practical applications for monitoring health and performance. New energy composites, which improve the performance of traditional metals, have been widely used in automotive manufacturing but have limited application in the sports industry. To bridge this gap, the study proposes integrating these advanced composites into sports equipment and facilities, utilizing IoT technology as the foundation for intelligent health monitoring. The research explores how IoT technology can enhance the promotional impact of fitness equipment within the sports industry. Additionally, the communication process for data assessment is conducted using the Priority-based Congestion-avoidance Routing Protocol (PCRP) to ensure efficient data transmission. The analysis of sports activities is performed by utilizing the data transferred through PCRP. Experimental results show that the proposed mechanism outperforms conventional models, achieving an energy efficiency of 0.502 joules (J), a delay of 0.407 seconds (s), and a throughput of 0.620. These results demonstrate the potential of combining IoT technology and new energy composites to revolutionize sports equipment and enhance fitness monitoring systems. These findings highlight the potential of combining IoT and advanced composite materials to revolutionize sports equipment, improve fitness monitoring, and contribute to the growth of the sports industry through enhanced data management and energy-efficient technologies.

Keywords: Energy; IoT; Sports Fitness Equipment; Sports Economics; Health Management

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1. Introduction

East Asian countries, having experienced prolonged economic affluence, have become critical destinations for international sports enterprises and events. Particularly, China, Japan, and Korea have frequently hosted noteworthy sporting occasions, like Olympics and the FIFA World Cup. Moreover, the domestic sports industries have steadily expanded over past few decades [1]. Particularly, professional leagues in baseball, soccer, basketball, and volleyball have thrived and gained prominence in the sports industry both in terms of size and quality [2]. East Asian professional sports teams typically attain financial support from large corporations and authorize their business goals in ways that differ from their Western counterparts. While western teams prioritize profit maximization, many Asian teams are viewed as extensions of corporations and are expected to recognize financial losses [1, 3]. Despite these distinctive characteristics, investigation in sports economics and management has largely overlooked Asian sports industry, leaving a gap in our understanding of this unique sector [4]. Thirusubramanian and Mohanarangan discuss the research on ECG monitoring with IoT, cloud, and fog computing, which is used on fitness equipment in sports economics through shared technologies. Both focus on real-time data collection via IoT, with cloud and fog computing improving data management and performance tracking. Additionally, machine learning techniques used for medical analysis can optimize athlete performance. These technological overlaps make the healthcare study a relevant reference for your paper on sports management and fitness equipment [5]. Researchers should examine the interrelation between environmental concerns and sports management practices. Along with Business Research Company's 2023 Sports Global Market Report, the global sports industry is expected to augment from $480 billion in 2022 to $512.1 billion in 2023 [6]. Remarkably, sporting events have environmental implication. For example, the Rio 2016 Olympics generated 4.5 million tons of CO2, the 2014 FIFA World Cup in Brazil emitted 2.8 million tons, and the 2010 South Africa World Cup produced approximately 2.7 million tons of CO2 [7, 8]. The sports industry has probable environmental implications, counting pollution and greenhouse gas emissions [9]. To alleviate these effects, policymakers and managers should prioritize environmental considerations in sports-related decisions, counting production and manufacturing of sports clothing and equipment, construction of sports venues, and hosting of major international sporting occasions while sports are valuable for human health, the sports industry and related actions, like venue construction, must focus on environmental protection and sustainable resource management [10, 11]. Furthermore, global sporting events ought to prioritize sustainability to care for the environment [12]. Inventiveness like plummeting air pollution and carbon emissions should be at the forefront. The FIFA World Cup Qatar 2022 demonstrates this commitment, becoming a trailblazing representation for eco-friendly international sporting events [13].

Amidst the global energy catastrophe and environmental alarms, the detection of high-performing thermoelectric materials and progressive energy technologies has been converted as a priority. Composite materials offer a unique solution by combining the strengths of multiple components [14]. They influence complementary possessions of individual materials to attain heightened performance that exceeds what any single material could suggest [15]. This pioneering mechanism is transforming the applications of composite materials in vital regions, like energy generation, materials science, and even sports apparatus, shaping their critical part in modern society [16, 17]. Sports fitness and facilities equipment need materials with high sturdiness and energy absorption competences to endure the strains of their usage [18]. The study has primarily focused on the effect of the IoT on the fitness industry, discovering its probable advantages and giving guidelines for its application in sports fitness scenarios [19]. Researchers have also focused on inspecting smart wearable equipment, measuring their technological and market potential. The studies accentuate vital part of these devices in tracking user activity and physiological parameters [20, 21]. By wearing smart wearables, entities can optimize their exercise routines and encourage healthier lifestyles [22, 23]. To entirely encirclement the big data era, the internet essential permeate every side of human existence, both professional and personal. By peeking through the research on fitness clubs, a new fitness mechanism is presented that incorporates the internet and cutting-edge energy materials [24]. The work deliberates the anticipated future advancements of this elevated mechanism and offers strategies to efficiently incorporate these advancements [25, 26].

The influence of IoT integration in Western fitness sectors has been extensively investigated in previous decades, but research on Asian sports industries, particularly those in China, Japan, and Korea has been noticeably lacking. This absence restricts our knowledge of how IoT technology affects sports administration and economics in these areas. Addressing this gap is crucial to creating region-specific plans that maximize IoT's potential to improve the dynamics of the sports sector. In order to provide insights that might guide policy and practice, this study intends to examine the role of IoT integration in the Asian sports industry. This study aims to investigate the role of IoT integration and sustainable materials in the Asian sports sector, providing insights that could inform policy and practice.

This research investigates how energy-efficient fitness equipment with intellectual health monitoring systems by incorporating IoT impacts the industry of sports. By launching an IoT health management structure, the device's fitness equipment design principles and algorithms are investigated. Furthermore, the work presents incorporating new energy composites into fitness equipment and sports facilities. This is made probable by IoT and a consistent communication protocol, like PCRP, an energy-efficient multi-hop routing protocol, which enables energy-efficient data transmission. By encouraging more participation, reducing operating costs, and providing sustainable solutions, energy-efficient fitness equipment combined with Internet of Things technology may improve the sports sector. Real-time monitoring, customized health insights, and better facility management are made possible by IoT, which also improves decision-making and increases consumer engagement. This integration gives the sports industry a competitive edge and opens up new markets, which promotes expansion, sustainability, and improved financial performance.

In the study, the IoT fitness devices were tested within a health management system, focusing on energy efficiency and data transmission using the Priority-based Congestion-avoidance Routing Protocol (PCRP). This protocol enabled efficient data communication by choosing the transmission paths on the basis of Signal-to-Noise Ratio (SNR), Residual Energy (RE), and Node Congestion Level (NCL). By using three metrics energy consumption, communication delay, and throughput, the devices' performance was evaluated. The PCRP protocol was compared to traditional routing models (CBLTR, Cross-layer OLSR, and IPG), and it shows superior performance in reducing energy use, minimizing delays, and increasing throughput. These results highlighted the effectiveness of IoT fitness devices in promoting energy-efficient, low-latency communication within the network.

The presented work is arranged as stated: First section portrays the introduction part. Second section states a thorough review regarding effects of new energy fitness equipment on sports economics and management. Third section exemplifies the methodology presented. Results and evaluations are depicted in the fourth section. At last, the conclusion is presented in the fifth section.

2. Literature Review

Cao H investigated health management system that utilized IoT technology [26]. The text designates the algorithm and design ideologies of wearable fitness equipment within the IoT health management system's structure. It also evaluated several kinds of noise that affect the accuracy of the equipment and delivers methods for clarifying such noise. Moreover, the authors examined cloud service platforms and discourse possible applications of wearable fitness devices in community atmosphere. Employing elevated technology, the study generated wearable fitness devices and innovative health management mechanisms that gave detailed, standardized, and effectual data. The work empowered users with real-time monitoring, data-driven insights, and intelligent decision-making to optimize their health and fitness. As pointed out in a recent investigation, the vast mainstream (90%) of people actively employed social media apps with fitness features. Zhu J et al. introduced the effect of sports management practices on renewable energy and environmental sources [13]. By utilizing an online survey dispersed through environmental organizations in seven Asian countries, they investigated 439 responders with changing work experiences. The outcomes stated that despite their varied backgrounds, the responders overwhelmingly agreed on the requirement of incorporating sustainable practices into sports management. To endorse sustainable sports management, the research presented certain measures including: embracing green financing mechanisms, establishing a collaborative system for "green sports administration", enhancing public awareness by communication channels about environmental strategies in sports management, and exploring renewable energy resources for sports amenities, like swimming pools and stadiums.

In Yong Z's study [10], the IoT was integrated into a smart simulation mechanism for physical training in sports education. IoT-enabled wearable devices collected student movement details during training and rapidly transmitted it to intelligent system, permitting for real-time system updates. Utilization of wearable equipment in sports training and data acquisition is just one feature of the broader field of scientific monitoring in sports. The work investigated physical training data from wearable devices, employing an optimized data processing procedure to improve data accuracy. Chen L. and Zhu H. discovered the impact of virtual reality technology in promoting the advancement of the sports economy within the setting of national fitness initiatives [11]. The work examined virtual reality and national fitness and evaluated the features of office workers, by integrating their health status, common ailments, and daily routines. They also investigated virtual and traditional home fitness equipment, linking their capabilities and features. To increment home fitness equipment design, the issues with prevailing models were evaluated. Interviews, surveys, and on-site examinations were performed to analyze target users and their environments. The work recognized user pain points and needs, stated the actual fitness needs of office workers. Particularly, 80% of responders in a study on virtual reality-based national fitness initiatives documented the advantages of integrating somatosensory technology into fitness equipment for enhancing fitness outcomes.

To discourse the growing popularity of smart phones and the necessity for athlete performance monitoring, Huang Z et al. evaluated a smart physical fitness monitoring mechanism by employing IoT technology [9]. They designated many fitness parameters (e.g., endurance running, chest size, height, flexibility, sprints, body composition, vertical jump). RFID tags recognized athletes, and the particle swarm optimization strategy was used to the BP network to generate an athlete fitness valuation model. Simulations permit the detailed forecast of athletes' physical states, contributing cutting-edge technological and scientific strategies to elevate the efficacy of training schedules and bring a scientific procedure to physical conditioning. In the research by Zhang J and Mi Y [18], mechanisms for investigating new energy materials were conversed. These strategies incorporated energy absorption and thermoelectric testing, which assisted to quantify material properties. The work also evaluated the self-shrinkage and fabrication properties of carbon nanomaterials through experimental preparation. At last, these carbon nanomaterials were employed in sensor designs for a health monitoring data acquisition mechanism. Experiments exposed that when the water-to-ash ratio was diminished, the carbon nanomaterial slurry's self-shrinkage value was 74.68% lesser than under typical scenarios. Recurrent tensile tests on omni directional and rectangular sensors made of carbon nanomaterial at changing temperatures stated that the sensor's sensitivity coefficient ranged from 55.8 to 60.4, with a maximum variation of only 5%. This settled that the carbon nanotube omnidirectional sensor can notice stimuli. Song Y. and Cheng Y inspected the conversion of old and new driving forces in the Chinese industry of sports [1]. They recognized the key elements and implication of this transformation. The work outcomes recommend that technological improvements can afford new motivations, while structural modifications shape the new landscape. Furthermore, shared advancement fosters a novel strategy to drive this conversion, generating a dynamic and innovative sports industry. Dimitriadis et al. firm that promote sustainable products may increase sales and differentiate themselves in the market by attracting environmentally concerned consumers with eco-friendly workout equipment [27, 28]. Additionally, lower operating expenses boost the profitability of fitness facilities and health clubs. The long-term advantages of green technology, such energy savings and improved brand awareness, provide substantial development potential despite the potentially hefty initial investment. Eventually, by encouraging sustainability, increasing consumer demand, and boosting economic efficiency across several sectors, the incorporation of green exercise equipment has the potential to completely transform the sports business. New energy fitness equipment benefits the sports industry economically by reducing operational costs through energy-efficient technologies and expanding the market with eco-conscious consumers. Government incentives further lower costs. Managerially, it enhances operational efficiency, improves brand reputation, and drives innovation through technologies like IoT for monitoring energy use and performance. This equipment aligns with sustainability goals, helping sports organizations reduce environmental impact and improve financial performance.

Klöcker discusses an advancement in fitness technology like new energy equipment with IoT and sustainable materials, improving athlete performance and human capital by improving training efficiency and fitness outcomes [29]. This boosts national sports success by fostering a stronger, more competitive sports workforce. The stochastic models could be used to assess how adopting such technologies impacts long-term sports performance and success at the national level. New energy fitness equipment benefits the sports industry economically by reducing operational costs through energy-efficient technologies and expanding the market with eco-conscious consumers. Government incentives further lower costs. Managerially, it enhances operational efficiency, improves brand reputation, and drives innovation through technologies like IoT for monitoring energy use and performance. This equipment aligns with sustainability goals, helping sports organizations reduce environmental impact and improve financial performance.

2.1. Challenges

Despite technological limitations that encumber the widespread utilization of smart wearables [3], the existing applications face practical issues. To address these challenges, companies can improve their marketing exertions through advertising, outdoor campaigns, and public promotions [2]. Furthermore, government agencies should implement a comprehensive regulatory structure and support the advancement of permitting infrastructure for smart wearables to thrive.

3. Methodology

The research aims to investigate a cutting-edge set of fitness devices that employs the IoT for sports management mechanisms. This attempt will leverage two indispensable technologies: IoT and sports management technology. Integrating fitness devices and sports management technologies offers challenges, such as establishing a comprehensive knowledge base for demonstrating the efficiency of fitness equipment. By evaluating this knowledge, the promotional effect of the equipment can be more precisely calculated. Secondly, it is important to deal with the abilities of the IoT to gather real-time information that can assure constant, long-term communication amongst hosts and nodes within the IoT structure. Thirdly, it's critical that the system platform can deal with the incrementing variety of devices. It should be adaptable to several equipment changes and have scalability capabilities. This integrates combining fault detection and pre-diagnosis algorithms into the system as pluggable components. The mechanism should also make sure to ensure seamless communication between this plug-in and the main program.

The research investigates the integration of energy-efficient fitness equipment with IoT technology in the sports industry. It simulates data transmission and communication using the Priority-based Congestion-avoidance Routing Protocol (PCRP), focusing on optimizing energy efficiency, minimizing delay, and maximizing throughput. The performance of PCRP with other conventional models (CBLTR, Cross-layer OLSR, and IPG) was compared across varying conditions, such as different network sizes (100, 150, and 200 nodes). Additionally, it examines the use of IoT-enabled wearable devices for monitoring athletic performance and health metrics, highlighting their role in improving training and health management. The simulations assess by what means these devices when integrated into sports equipment, impact energy consumption, data communication, and overall system performance in real-world sports management scenarios.

Due to its capacity to facilitate continuous, real-time monitoring and data gathering from smart meters and grid sensors, IoT technology offers significant advantages over other comparable technologies in the detection of power theft. This real-time data collecting is scalable and simple to incorporate into big networks, enabling prompt identification of odd consumption patterns that could point to theft. Compared with traditional techniques, IoT systems gather and analyze vast amounts of data automatically, increasing accuracy and dependability without requiring human involvement. In addition, IoT allows for immediate alerts and automated responses to potential theft, enhancing efficiency and reducing operational costs. While other technologies like smart grids and SCADA systems also provide monitoring capabilities, they often lack the real-time detection, scalability, and automation that IoT systems offer, making IoT the more effective choice for electricity theft detection.

The system scheme is described and analyzed in detail below. The system solution model is shown in **Figure 1**.

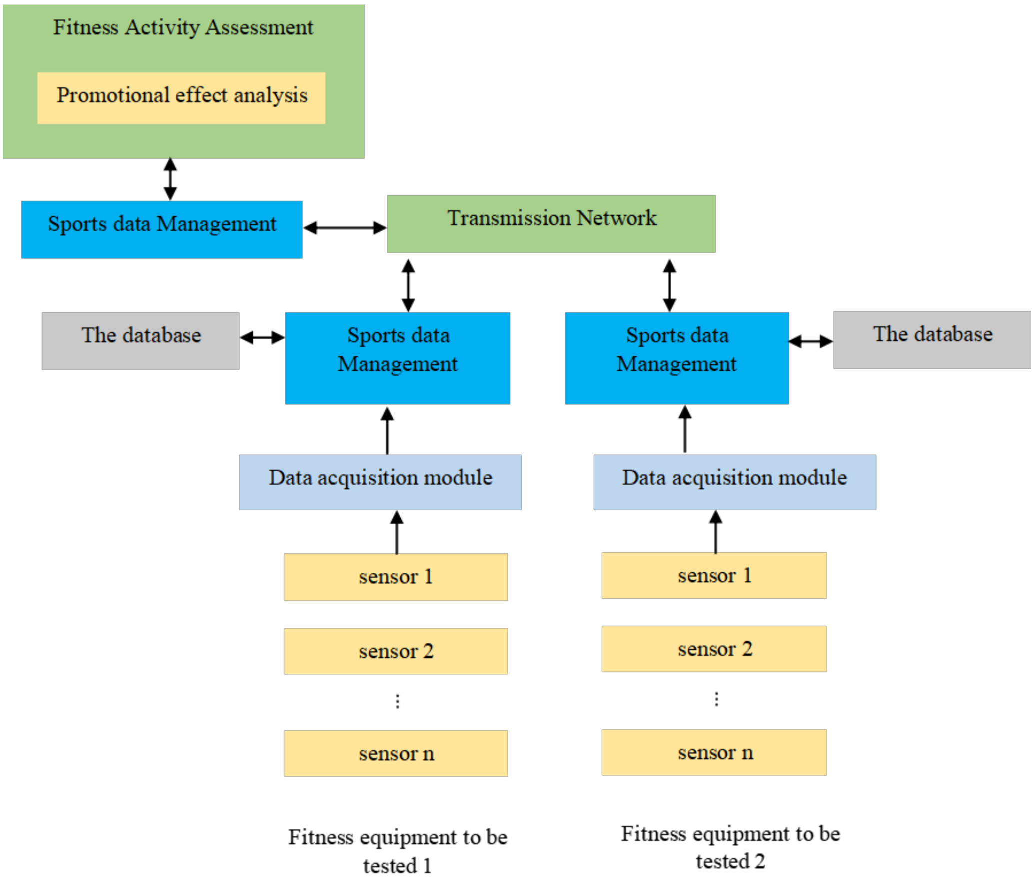

Figure 1. Basic Architectural Diagram.

3.1. Data Communication via PCRP

PCRP is a kind of routing protocol employed in sensor networks where data is transferred among nodes in multiple stages[12]. It is presented to reduce the amount of processing needed and routing overhead amongst sensors that are collecting data. For each hop, or transmission, the next node is selected according to signal-to-noise ratio (SNR), residual energy (RE), and node congestion level (NCL). The RE and NCL factors are shared between nodes by sending "hello" messages, while the SNR is measured by the node sending the data. Each node then chooses the next node to send data to base on which node has the least cost (best combination of SNR, RE, and NCL) and sends the data to that node. The data transmission and sending procedures are iterated until the gathered data arrives at its final destination, which is the Sink node. The PCRP is chosen for its superior performance in energy efficiency, reduced delay, and higher throughput when compared to other routing protocols including CBLTR, Cross-layer OLSR, and IPG. PCRP employs a fitness function that integrates Signal-to-Noise Ratio (SNR), Residual Energy (RE), and Node Congestion Level (NCL) to make informed routing decisions, improving the optimal path selection for data transmission. This approach is especially useful in applications of Internet of Things such as healthcare and sports management, where efficient data communication is critical. The design of the protocol prioritizes emergency data and efficiently handles congestion, both of which are necessary for the prompt delivery of vital information in medical situations. Although PCRP has several benefits, it is important to recognize its limitations, which include higher computing complexity and dependence on precise SNR measurements, which can be problematic in noisy or dynamic situations. Applications requiring dependable and efficient data transfer might use PCRP because of its customized design and validated performance measures.

Handling Latency, Packet Loss, and Security: In order to minimize packet volume and lower the chance of loss, PCRP incorporates data aggregation algorithms, which store and aggregate non-urgent data prior to transmission. To ensure that no important information is lost, urgent data is given priority and transmitted immediately. Furthermore, the system employed secure communication protocols, incorporating authentication and encryption techniques to protect data while it was being transmitted, in order to enhance security. Data protection is maintained by regular upgrades and access control systems, which also guarantee adherence to IoT security requirements and stop unwanted access.

(1) **Setup Phase**

All sensors have the same communication and power capabilities. They are presumed to be in fixed spot within a certain transmission range. The sensors are linked wirelessly and transfer data to a central node (sink). The sink performs as a hub, joining the network to the outdoor world. Based on the IEEE 802.15.6:20121 standard's network layout, every node is within two hops of the sink. Only and coordinates are employed when placing sensors because the calculations for sensor positioning (eq. 1) use a two-dimensional procedure. Due to the minimal deviation in z-axis movement upon sensor node repositioning, the z-axis is omitted from deliberations for sensor distribution.

(2) **Initialization Phase**

When the network is first initiated, the central hub (sink) transfers out a brief message covering its documentation and location. Each sensor device stores the sink's location data. Afterward, each sensor sends out "hello" messages that integrate its NCL, RE level, location, and ID.

(3) **Select Transmission Power**

Each node will demonstrate its transmission power according to distance between the node itself and the farthest node it must send the data to (which is nearby to the destination node). The distance amongst the sending and receiving nodes is measured utilizing the following formula:

$$\sqrt{(u_i - u_j)^2 + (v_i - v_j)^2} \tag{1}$$

In communication networks, nodes (i, and j) interchange data over definite distances (d). To confirm effective data reception, the transmitting node must produce signals with adequate strength so that even the most distant node can decipher them if chosen as the next data relay point. Defining the optimal transmit power includes exploiting a mathematical calculation, called the transmission equation.

$$p_t = p_r + 20\log\left(\frac{4\pi d}{\sigma}\right) - g_t - g_r(dbm) \tag{2}$$

The maximum distance amongst a transmitter and receiver is exemplified by: p_t Transmit power, p_r : Receiver sensitivity, d : maximum distance, l : Wavelength, g_t : Gain of transmitting antenna, and g_r : Gain of receiving antenna.

The path loss mode, energy model, NCL, SNR and fitness computation are computed as detailed in [15].

(4) **Routing Phase**

Communication happens step-by-step over multiple transmissions. The node with the maximum fitness value amid neighboring nodes is chosen as the forwarding node to the receiver (sink). The next node to forward the data is designated according to the packet type in the transmission queue. For steady data flow, sensors gather data constantly but transmit it occasionally. This procedure is only employed for sensors that are not critical for the patient's well-being. For example, a blood pressure sensor will gather data continuously but only send it to the sink after a set time period known as the data aggregation time interval. Throughout this interval, the sensor stores all packets in its buffer space. This mechanism is known as data aggregation.

Throughout a specific interval, emergency data packets are arranged and transferred directly through an emergency route without aggregation. Once the interval ends, the sensor combines all stored packets, excerpts the lowermost, uppermost, and middling values, and transmits only these three packets to the sink. These aggregation and filtration procedures preserve sensor energy, condense network traffic, and extend the network's lifecycle. Naturally, the data packets are routed to the subsequent node with the finest connectivity. Nevertheless, for imperative data, a precedence level is allotted based on its importance. Sensors have discrete queues for packets with diverse priority levels. The choice of which next node to use is made according to the priority: For regular data, the next node is designated based on the maximum connectivity value. For emergencies, a specialized function is utilized to select the next node with the maximum connectivity value.

The detailed algorithm of the PCRP for routing data is as follows: When two data packets share a similar priority, they are programmed on a first-come, first-served basis. After implementing this algorithm, a fitness score is premeditated. The fitness score demonstrates the next-hop node for the data packet.

3.2. Sports Activity Management at IoT Server for Promotional Effects

Wearable equipment and IoT are transmuting sports by contributing innovative ways to monitor and enhance performance. These IoT wearables, fortified with sensors, gather and evaluate data like biomarkers and other indicators of an athlete's health and fitness. By tracking these details, coaches and athletes can attain insights into the athlete's competencies, detect potential health issues, and optimize their training programs to augment overall performance. Virtual networks support tracking athletic performance in sports, like golf and cycling, by assembling and transporting data via PCRP for investigation. These systems aid in managing IoT-related tasks in sports management and foster a healthier lifestyle by exploiting IoT-backed tracking devices that monitor physical activity for the examination.

The experiment evaluated the performance of fitness devices integrated with IoT technology for sports management, using a wireless sensor network and the Priority-based Congestion-avoidance Routing Protocol (PCRP) to manage data transmission. Fitness equipment was equipped with smart wearables and IoT sensors to collect real-time data on athlete health and performance, with the sensors communicating wirelessly to a central hub. The network was set up according to IEEE 802.15.6:20121 standards, and key metrics such as energy consumption, delay, and throughput were measured across varying numbers of sensor nodes (100, 150, 200). The protocol used a fitness function based on Signal-to-Noise Ratio (SNR), Residual Energy (RE), and Node Congestion Level (NCL) to select the optimal node for data transmission. Data was aggregated and transmitted through the most efficient paths, with priority given to critical data like emergency signals. Results showed that the PCRP mechanism outperformed traditional protocols like CBLTR, Cross-layer OLSR, and IPG in terms of energy efficiency, reduced delay, and increased throughput, demonstrating the benefits of integrating IoT with fitness devices for optimized sports management.

The study introduces an energy-efficient communication model using the Priority-based Congestion avoidance Routing Protocol (PCRP) for loT-enabled fitness devices in sports management. The model optimizes energy consumption, data transmission, and network performance by leveraging key metrics such as Signal-to-Noise Ratio (SNR), Residual Energy (RE), and Node Congestion Level (NCL). Energy consumption is calculated based on transmission power over a distance, with the transmission power equation

$$P_t = \frac{(4\pi d)^2 \cdot P_r}{G_t \cdot G_r \cdot \lambda^2} \tag{3}$$

and the energy consumption over time given by

$$E_t = E_{t\text{–}1} \text{–} R_t. \tag{4}$$

PCRP reduces energy usage by implementing data aggregation for non-urgent packets, minimizing retransmissions. The model was validated by comparing PCRP with traditional protocols (CBLTR, Cross-layer OLSR, and IPG) across energy, delay, and throughput metrics. The results demonstrated that PCRP outperforms the other protocols in terms of energy efficiency (up to 6% more efficient), reduced delay (20–38% lower), and increased throughput (23– 89% higher). Overall, PCRP provides a superior solution for optimizing loT communication in fitness devices, confirming its effectiveness in enhancing performance across various metrics.

4. Results

4.1. Comparative Assessment

A comparative evaluation is executed in this section based on energy (J), throughput and delay (s). The proposed PCRP mechanism is compared with traditional approaches, such as CBLTR[20], Cross-layer OLSR[24], and IPG[22]. Here, the comparative assessment is taken based on the number of nodes, which is 100, 150 and 200.

4.2. Comparative Metrics

Energy: This measurement explains the energy utilized by each node in transmitting packets and examines the overall energy utilization of the entire network. To apprise the network lifetime using the residual energy, the rate at which nodes lose energy is demonstrated as illustrated in the work by Ang and Choi[14].

$$e_r = \left(\frac{E^R_{t_A} - E^R_{t_{A+1}}}{t_A - t_{A+1}} \right) * \left(\frac{R_n + 1}{N} \right) \tag{5}$$

where $E^R_{t_A}$ denotes available energy of the node at time t_A ,

R_n denotes the number of retransmissions per packet, $E^R_{t_{A+1}}$ denotes available energy of the node at time t_{A+1}.

Delay: The delay in the communication is evaluated based on the number of nodes in a routing path in the network.

Throughput: Network throughput calculates the rate of messages transferred over a communication channel (like radio or Ethernet). These data can be transferred through logical or physical connections or network nodes. Throughput is usually articulated in bits per second (bps) or data packets per second (p/s or pps) or per time slot.

The metrics of throughput, delay, and energy in the study were derived through simulation-based evaluations rather than real-world deployments or purely theoretical calculations. The experiments simulated various network scenarios with 100, 150, and 200 nodes, comparing the performance of the proposed Priority-based Congestion-avoidance Routing Protocol (PCRP) with conventional routing protocols such as CBLTR, Cross-layer OLSR, and IPG. The results demonstrated on how PCRP outperformed the others regarding the energy efficiency, throughput, and delay. Throughput was assessed by the data transfer rate, delay was measured as the time taken for data to reach its destination, and energy was evaluated by the consumption during data transmission, all of which contributed to demonstrating the superior performance of PCRP in network communication.

4.2.1. Comparative Evaluation

This section details the comparative analysis of various routing protocols by altering the number of nodes in the network as 100, 150, and 200, respectively.

(1) **Analysis Using 100 Nodes**

Figure 2 illustrates the comparative assessment of the proposed mechanism with other conventional models based on energy, throughput and delay with 100 numbers of nodes. **Figure 2**(**a**) represents the evaluation based on average delay. The proposed method attained delay of 0.563, whereas the CBLTR, Cross-layer OLSR, and IPG attained 0.873(s), 0.793(s), and 0.731 (s) at 2000th round. For the round 1, the proposed method attained a delay of 0.163, whereas CBLTR, Cross-layer OLSR, and IPG attained the delay of 0.196 (s), 0.189(s), and 0.163(s). **Figure 2**(**b**) represents the examination based on energy. At round 1, the proposed method attained the energy of 0.9995 (J), however CBLTR, Cross-layer OLSR, and IPG attained energy of 0.9994 (J), 0.9996 (J), and 0.999 (J). However, the proposed PCRP mechanism attained the maximum energy of 0.419 (J), while CBLTR, Cross-layer OLSR, and IPG attained energy of only 0.050 (J), 0.159 (J), and 0.254 (J) at 2000th round. **Figure 2**(**c**) exemplifies the examination of the presented PCRP mechanism based on throughput. At round 1, the proposed method attained a throughput 1, however CBLTR, Cross-layer OLSR, and IPG attained energy of 1, 1, and 1, respectively. The proposed mechanism attained the maximum throughput of 0.419, whereas the CBLTR, Cross-layer OLSR, and IPG strategies attained the throughput of 0.0507, 0.160, and 0.254 for the number of rounds 2000.

(2) **Analysis Using 150 Nodes**

Figure 3 illustrates the comparative assessment of the proposed mechanism with other conventional models based on energy, throughput and delay with 150 nodes. **Figure 3**(**a**) represents the evaluation based on average delay. Initially, for round 1, the proposed method attained a delay of 0.146 (s), whereas CBLTR, Cross-layer OLSR, and IPG attained 0.150 (s), 0.139(s), and 0.137(s). However, the proposed method attained the lowest delay of 0.439 (s), whereas the CBLTR, Cross-layer OLSR, and IPG attained 0.760(s), 0.643(s), and 0.576 (s) at round 2000. **Figure 3**(**b**) represents the examination based on energy. At round 1, the proposed method attained 0.9995 (J); however, CBLTR, Cross-layer OLSR, and IPG attained energy of 0.9994 (J), 0.9996 (J), and 0.999 (J). The proposed PCRP mechanism attained an energy of 0.557 (J), however the CBLTR, Cross-layer OLSR, and IPG attained energy of only 0.231 (J), 0.335 (J), and 0.428 (J) at 2000 round. **Figure 3**(**c**) exemplifies the examination of the presented PCRP mechanism based on throughput. At round 1, the proposed method attained a throughput 1, however CBLTR, Cross-layer OLSR, and IPG attained energy of 1, 1, and 1, respectively. The proposed mechanism attained a throughput of 0.557, whereas the CBLTR, Cross-layer OLSR, and IPG strategies attained throughput of 0.231, 0.335, and 0.428 for round 2000.

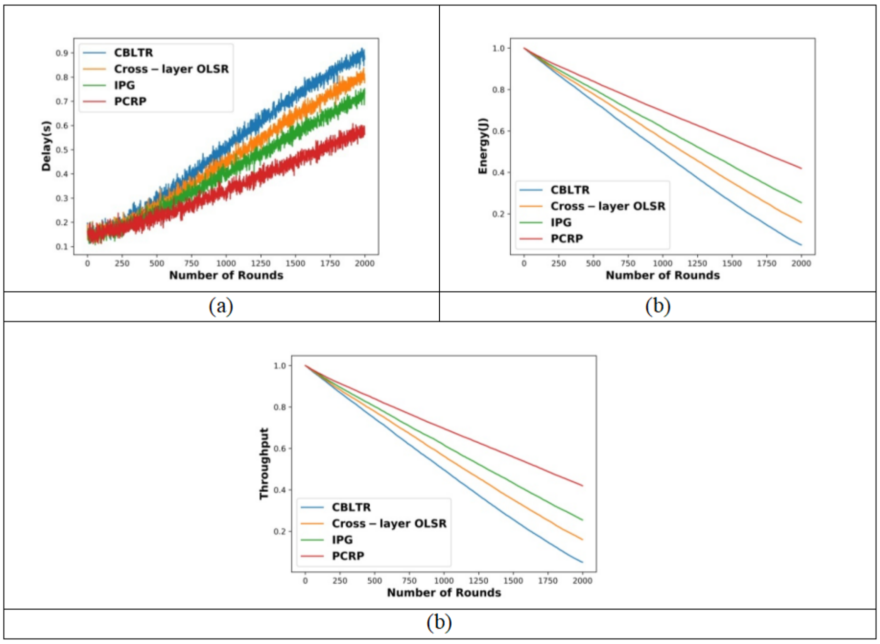

Figure 2. Comparative Evaluation with 100 Numbers of Nodes, (**a**) Delay, (**b**) Energy and (**c**) Throughput.

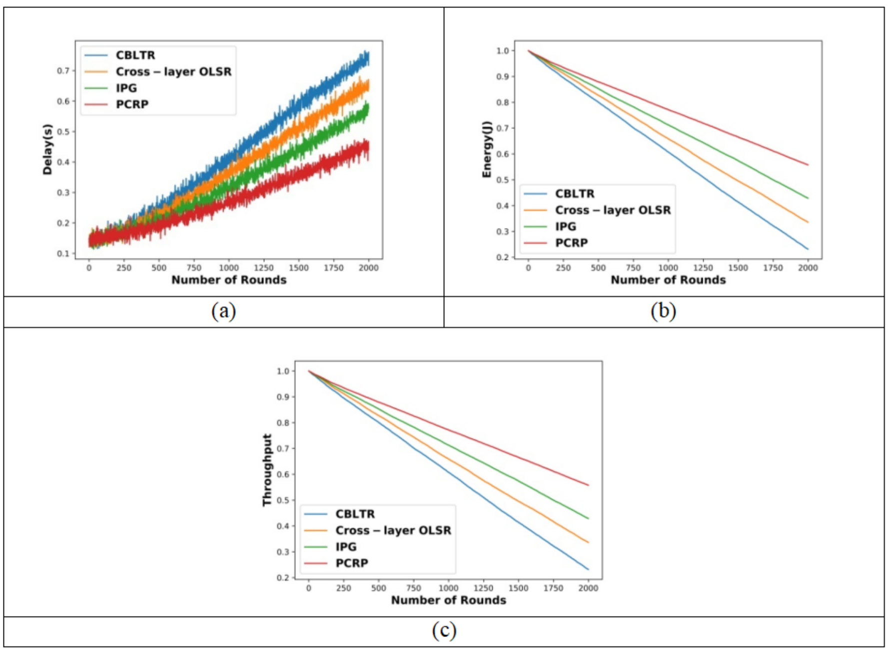

Figure 3. Comparative Evaluation with 150 Numbers of Nodes, (**a**) Delay, (**b**) Energy and (**c**) Throughput.

(3) **Analysis Using 200 Nodes**

Figure 4 illustrates the comparative assessment of the proposed mechanism with other conventional models based on energy, throughput and delay with 200 numbers of nodes. **Figure 4**(**a**) represents the evaluation based on average delay. For the round 1 the proposed method attained a delay of 0.141 (s), whereas CBLTR, Cross-layer OLSR, and IPG attained 0.166 (s), 0.149(s), and 0.150(s). The proposed method attained delay of 0.407 (s), whereas the CBLTR, Cross-layer OLSR, and IPG attained 0.659(s), 0.607(s), and 0.501 (s) for 2000 rounds. **Figure 4**(**b**) represents the examination based on energy. At round 1, the proposed method attained 0.9995, however CBLTR, Cross-layer OLSR, and IPG attained energy of 0.9994 (J), 0.9996 (J), and 0.999 (J). The proposed

PCRP mechanism attained an energy of 0.502 (J), however the CBLTR, Cross-layer OLSR, and IPG attained energy of only 0.474 (J), 0.327 (J), and 0.421 (J) for round 2000. **Figure 4**(**c**) exemplifies the examination of the presented PCRP mechanism based on throughput. At round 1, the proposed method attained a throughput 1; however CBLTR, Cross-layer OLSR, and IPG attained energy of 1, 1, and 1, respectively. The proposed mechanism attained a throughput of 0.620, whereas the CBLTR, Cross-layer OLSR, and IPG strategies attained throughput of 0.328, 0.422, and 0.502 for round 2000.

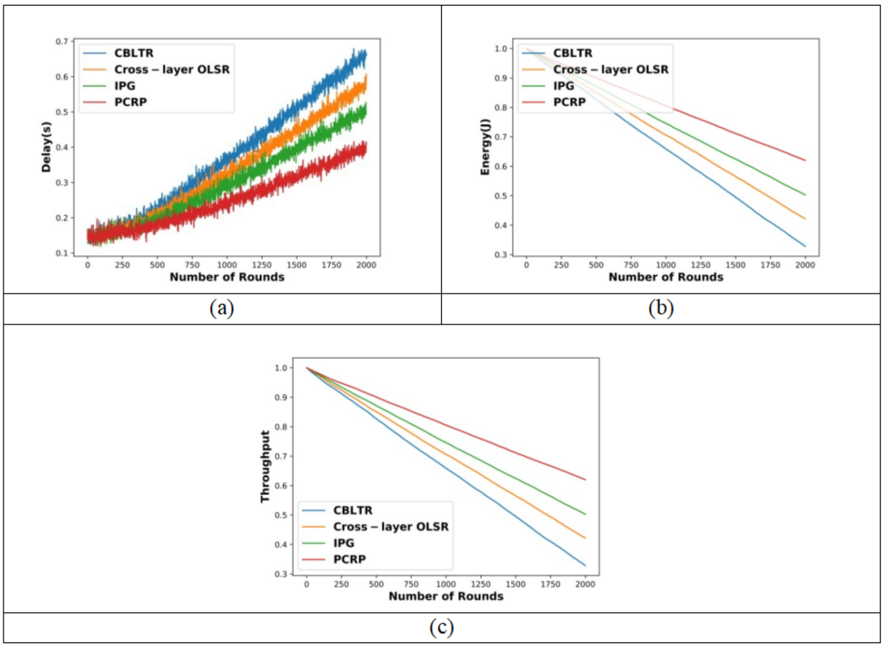

Figure 4. Comparative Evaluation with 200 Numbers of Nodes, (**a**) Delay, (**b**) Energy and (**c**) Throughput.

5. Robustness Test: Understanding the Influence of Economic Principles on Sports Management Decisions

In analyzing the robustness of sports management decisions, it is essential to integrate economic principles that directly impact decision-making processes. Sports management decisions are strongly influenced by economic principles, particularly when it comes to ideas like supply and demand, resource allocation, and market systems. Market dynamics have a direct impact on pricing strategies for broadcasting rights, merchandising, and tickets. Similar to this, sports organizations efficiently use their limited resources, taking opportunity costs into account while striking a balance between player pay, facilities, and marketing initiatives. Based on their capacity to produce income, labor economics including human capital theory guides choices on player recruiting and compensation. By generating income from ticket sales, sponsorships, and broadcasting agreements, sports management also has an effect on the economy and serves to create jobs in the sector and its associated industries. Furthermore, effectively run teams or tournaments may improve a region's reputation, attracting investment and strengthening local economies. Consumer behavior, pricing tactics, economic effect studies, and public policy choices all demonstrate the relationship between economics and sports management and have an impact on both the financial stability of sports organizations and overall economic results.

6. Comparison of Results from Robustness Test and Primary Methodology

The robustness test and primary methodology both emphasize the integration of IoT technology, but with different emphases. The robustness test specifically assesses the performance of the Priority-based Congestion-avoidance Routing Protocol (PCRP) in managing energy consumption, delay, and throughput across different network sizes, viewing that PCRP outperforms traditional protocols like CBLTR, Cross-layer OLSR, and IPG in terms of energy efficiency, reduced delay, and higher throughput. In contrast, the primary methodology focuses on the broader application of IoT-enabled fitness equipment in sports management, emphasizing real-time health monitoring and data communication. While both methods assess the efficiency of IoT systems, the robustness test offers a more detailed analysis of network performance, whereas the primary methodology centers on the integration of IoT for optimizing athletic performance and health management. The comparison highlights how PCRP enhances network performance in sports IoT systems, while the primary methodology focuses on leveraging IoT technology to improve sports management and fitness monitoring.

7. Policy Implications

Integrating IoT technology and new energy composites in sports equipment can help policymakers promote physical activity, reduce healthcare costs, and support sustainability goals. IoT-enabled devices can track health in real-time, encouraging healthier lifestyles while energy-efficient sports equipment can minimize environmental impact. These innovations also enhance the sports management, enabling more efficient facility operations and cost savings. Manufacturers can tap into the growing demand for eco-friendly, high-tech products, boosting the economy and creating jobs.

8. Conclusions

This study highlights the potential of IoT and energy-efficient materials to transform the sports industry by enhancing health management, sustainability, and performance tracking. These technologies offer significant benefits for individual health, environmental sustainability, and economic growth. IoT technology offers advanced and practical appearances in fitness trackers and AI-based health management system. New energy composites are innovative materials that can elevate traditional metals, predominantly with enhanced performance. The paper showcases the impact of energy fitness equipment in encouraging physical activity and meeting national health goals by incorporating IoT technology. The research discovers how IoT sensors combined into sports facilities and fitness equipment can communicate data to a server employing a secure communication protocol. This mechanism consents for the estimation of the influence of these new fitness devices on sports participation and physical activity management. Initially, the data is communicated using PCRP multi-hop routing protocol and the data is assessed for the promotional effects of fitness equipment that are based on minimum energy consumption and thereby, managing the sports economy efficiently. The experiment results stated the presented mechanism outperformed other conventional models and attained an energy of 0.502 (J), delay of 0.407 (s) and throughput of 0.620. Looking forward, the integration of IoT and energy-efficient materials will likely continue to evolve, creating opportunities for further innovation in product development, smart stadiums, and data analytics. Future studies could focus on refining the impact of these technologies on athlete health, sustainability outcomes, and the business models within sports management.

Author Contributions

Conceptualization, S.W.; formal analysis, S.W.; validation, S.W.; writing—original draft preparation, S.W.; investigation, D.D.; software, D.D.; writing—review and editing, D.D.; project administration, D.D. All authors have read and agreed to the published version of the manuscript.

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Institutional Review Board Statement

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Informed Consent Statement

Not applicable.

Data Availability Statement

No datasets were generated or analyzed during the current study.

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Conflicts of Interest

The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript; or in the decision to publish the results.

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