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Fog Computing in Sports: A Systematic Survey

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Abstract
The use of Internet of Things (IoT) in sports leads to an exponential growth in data generation, It creates a need for efficient processing and analysis mechanisms. Cloud computing works efficiently in such situations but due to its central location there are some issues like latency,Increased workload on cloud and Network congestion due to huge data transfer to cloud. Fog computing is technology that extends the cloud computing services closer to the data source and offers promising solutions for real-time analytics. In sports there is a need to process data in a time-effective manner such as data related to finding strategies of the opponent team or Players health related data which needs to process time effectively. Fog Computing may work effectively. This paper reviews existing literature on the applications of cloud computing and fog computing in sports. The study explores the benefits, challenges, and future directions in use of fog computing in sports Domain.
Keywords: Fog Computing, Sports, IoT, Real-time Analytics, Performance Monitoring

1. Introduction

Use of IoT is increasing across all sectors such as healthcare, smartcity, transportation etc.. The sports industry is undergoing a digital transformation. These devices generate vast amounts of data providing valuable insights into athlete performance, training effectiveness, Team tactics and fan engagement etc.[1].Cloud computing is working effectively in such situation with its large resources. Cloud can process the vast amount of data at centralized data centers, transmitting all data to cloud for processing introduces significant latency, which is not acceptable for real-time applications[2]. Fog computing addresses this issues of cloud by distributing computing tasks among the resources closer to the edge of the network. Fog nodes perform data processing, filtering, and analysis locally to reduce the burden on the cloud. It reduces the volume of data transmitted to the data center, avoiding data congention which results in improving response time [3]. This study systematically examines the current state of use of fog computing in sports applications. This study highlights the potential to improve performance .

2. Methodology : This study follows a structured literature survey approach to examine the role

of fog computing in sports analytics. The study has been done in three different steps: literature search, selection criteria, and data extraction & analysis. A comprehensive search has been done. To find research articles in journal, conference proceedings, and studied papers published between 2013 and 2024 to capture both foundational and recent advancements in the field.

2.2 Selection Criteria for research Article.

The selection of studies was based keywords Fog computing ,sports analytics, real-time sports data processing, athlete performance tracking.

3. Data Extraction & Analysis

While going through literature we came across 11 papers describing the use of IoT in cloud and in Fog Computing in sports Domain. A comparative analysis of the selected studies was conducted to identify trends, technological advancements, and existing gaps in Cloud and fog computing applications in sports analytics. The use of IoT devices is increasing in the sports in innovative ways. A system called iBall to track a ball's 3D trajectory and spin using embedded sensors and wireless technology is developed. It works better than traditional motion tracking methods. The iBall integrates wireless ranging, inertial sensing, and motion models into a non-linear error minimization framework[4]. A novel sports system architecture of automatic player monitoring is proposed , Which is one of the first real implementations of IoT technologies in sports. It uses an ultra-low-power Hybrid Sensing Network (HSN) to capture real-time physiological and environmental data. This data is transmitted to a cloud platform.[5] The use of these cloud Iot based systems are not only limited to sports monitoring but it extends to training also. The (Hong-jiang et al., 2013) cloud-based sports training auxiliary system is proposes to continuously collect and analyze athletes' movement, physiological, and biochemical data in real time using advanced digital technologies. This system leverages a hybrid cloud model to efficiently store, compute, and manage vast amounts of training data, ensuring secure access and intelligent analytics through cloud services like IaaS, PaaS, and SaaS[6].Similarly (Wang et al., 2018) an IoT-based framework for racket sports training using a wireless wearable sensing device (WSD) with MEMS motion sensors was proposed to identify badminton strokes and

assesses player skill It is a cost-effective, real-time monitoring which shifted training from subjective judgment to objective[7]. The fog computing reduces latency, enabling real-time data processing essential for applications like health monitoring, live performance monitoring and immediate feedback during training sessions. As data is handled locally near to data sources it also decreases bandwidth usage. These benefits make fog computing a compelling choice for sports analytics, where timely and secure data processing is crucial[8]. Many researchers used fog computing in data processing and data analytics. The fog computing mitigating the issues in cloud by handling the sport data locally. Many research papers explaining and proposing the use of fog computing in sports data processing and analysis.The paper [9] importance of video analytics in sports analysis, particularly for match evaluation by extracting real-time data coaches, sports scientists, and analysts providevaluable insights into players' physical conditions. With the increasing adoption of IoT-based sports applications, fog computing emerges as a viable solution for real-time distributed processing of video streams. Its decentralized architecture enhances performance evaluation by enabling efficient data analysis closer to the edge which Future research should focus on improving transparency, integrating advanced machine learning algorithms, and refining tracking methods for player positioning, fatigue assessment, and injury monitoring to further enhance sports analytics.This study explores the use of Smart Fog Computing in sports science by combining heart protein analysis with aerobic exercise for accurate assessment. Experiments with rats show that this approach effectively tracks heart protein changes, boosts metabolism, and aids digestion. The results suggest it could help improve fitness and performance evaluation [10].

This Paper (Luo, 2023) addresses the challenge of traditional sports video content distribution and acceleration in mobile fog computing (MFC). To optimize mobile user access delays, an interest-based caching strategy is proposed, considering MFC server storage constraints, user preferences, and video file sizes. The strategy selectively caches and updates video objects to maximize user satisfaction. Simulation results demonstrate improved cache hit rates and system stability, with a 15% reduction in video retrieval delay compared to existing methods, highlighting its effectiveness in enhancing sports video content delivery[11].

An Internet of Things-Fog computing based game-theoretic decision-making model is proposed for provisioning in-depth analysis of athlete performance in a time-sensitive manner. The model works between the sports athlete and monitoring officials for effective decision-making services. The simulation was performed over a data set of four cricket players comprising 80 120 data. Based on the simulation results, the presented model was able to register enhanced performance in terms of sensitivity, specificity precision , and f-measure, improved battery efficiency and stability [12].

The fog computing and an Internet of Things (IoT) based architecture are proposed to produce new technical strategies and to avoid disabilities. Players and spectators are monitored with

sensors such as blood pressure, body temperature, heart rate, location etc. The data obtained from the sensors are processed in the fog layer and the resulting information is sent to the devices of the technical team and club doctors. For this, a task management algorithm based on priority queue and list of fog nodes is modified in the fog layer[13]. The comprehensive survey on time-sensitive applications implemented in fog computing environments. The goal is to research applications implemented in fog computing architectures and the temporal requirements of these applications. Our research is important for the area of real-time systems since the concept of systems that respond in real time has presented various understandings and concepts[14]. The COVID-19 affects all the domains of our society. A novel six-layer model facilitates the sports talent identification remotely using the various latest Information and Communication Technologies like IoT, fog and cloud computing. All the stakeholders like experts, coaches, players, institutes etc. are taken into consideration. The framework is mobile, widely accessible, scalable, cost-effective, secure, platform/location independent and fast. A brief case study of cricket talent identification using the proposed framework is also provided[15]. This study explores the use of fog computing and deep learning to improve basketball referee training in China's national fitness strategy. As basketball grows in popularity, higher standards for referees' knowledge, skills, and fitness are needed, making advanced technology essential for their development[16]. This review highlights the transformative role of data science in sports, enhancing athlete performance and fan engagement. Advanced analytics, machine learning, and wearables help optimize training, prevent injuries, and refine game strategies. Meanwhile, big data and predictive modeling personalize fan experiences, strengthening their connection with teams. As technology advances, data-driven approaches will continue to revolutionize sports[17]. Fog computing has many advantages over existing cloud technology in sports data processing and sports data analytics tasks like Motion Analysis, Player Performance Analytics,Fan Engagement etc..

3. Analysis

Latency in Real-Time Processing: Cloud-based systems introduce delays, making them less suitable for real-time sports analytics and live feedback. Fog computing reduces latency, but efficient scheduling and processing at the edge remain a challenge.

Scalability and Resource Constraints: Increasing IoT adoption in sports generates massive data streams, requiring scalable storage and computing power. Fog nodes have limited processing capabilities, necessitating optimized resource allocation.

Energy Efficiency and Power Constraints: Continuous data processing in cloud-based systems consumes significant energy. Fog computing reduces transmission costs but shifts the power burden to edge devices, requiring energy-efficient algorithms.

Accuracy and Reliability of Analytics Models: Machine learning models for player tracking, injury prediction, and performance evaluation require large, high-quality datasets. Model accuracy can be affected by environmental conditions, sensor limitations, and variations across sports.

System Reliability and Fault Tolerance: Ensuring continuous availability of fog nodes is challenging due to hardware failures or network disruptions. Dynamic fault-tolerant mechanisms are needed to prevent data loss and system downtime.

Future research should focus on addressing these challenges and exploring new applications of fog computing in sports. Areas of interest include optimizing resource management in fog networks for real-time sports analytics, integrating artificial intelligence (AI) and machine learning (ML) algorithms into fog nodes for advanced performance analysis.

4. Conclusion: This study highlights the growing role of fog computing in sports, addressing the limitations of cloud-based systems by enabling real-time data processing closer to the source. By leveraging IoT and fog computing, sports analytics can enhance player performance, optimize team strategies, and improve spectator experiences. The literature review demonstrates that fog computing effectively reduces latency, alleviates network congestion, and ensures timely decision-making in critical sports scenarios. However, challenges such as resource constraints, energy efficiency, and fault tolerance must be addressed to fully realize its potential. Future research should focus on optimizing resource allocation, integrating AI-driven analytics, and improving the reliability of fog-based systems. As technology evolves, fog computing is expected to revolutionize sports analytics by providing faster, smarter, and more efficient solutions.

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