[1] Chongjiang Zhan
[2] Yunhao Tang
[3] * Pengtao Cui

Research on Football Field Monitoring System Based on Internet of Things

Journal of Electrical Systems

Abstract: - Football is one of the three major sports in the world, and it is an important part of a country's sports. At present, an important method of football tactics research is to use the Internet of Things data monitoring system to collect various data generated during the game and training, and then use computer software to obtain kinematic information. In order to improve the efficiency of physical energy allocation and technical and tactical level of athletes, and timely discover the problems of athletes and the implementation of coaches' tactics. Coaches urgently need a system that can collect various sports data in time. This paper proposes a football field data monitoring system based on the Internet of Things, which tests the performance of data monitoring through MATLAB. Finally, the validity and scientificity of the data monitoring system were initially verified.

Keywords: Football; Information collection; Internet of things; Tactics; Computer simulation.

I. INTRODUCTION

In the past 30 years, since the reform and opening up, China's economy and military have developed rapidly, its hard power has been significantly enhanced and enter into the world power scope. With the continuous improvement of China's comprehensive national strength, the demand for soft power of our country is increasing with each passing day [1]. As an important part of soft power, sports strength has received more and more attention from the public and received more policy support [2]. In recent years, our country has achieved excellent results in the Olympic Games and other world competitions. However, there exists the problem of "prefer certain subjects" in the development of physical education in China. For example, our country maintains a strong competitiveness in table tennis all year round and always leads the progress of the world table tennis level. However, China's performance in the "three big ball" project is not satisfactory. Football, in particular, has been unable to "rush out of Asia" to complete the World Cup breakthrough.

Compared with the European football powerhouse, there are historical reasons and realistic factors for China's backward football level. The historical reason lies in the late start of China's football development. China's First A Football League was not formally established until 1994 [3]. In terms of experience and system design, there exists a huge gap compared with the English Premier League and La Liga, which have a long history. However, considering the realistic factors, there is a possibility for China to catch up in the football project. Realistic factors mainly include two aspects: physical function and technical and tactical level [4]. There is an obvious gap between Asians and Europeans in terms of physical function and height. Therefore, it is an inevitable trend to improve the quality of athletes and develop their skills and tactics through scientific methods.

Among the all kinds of technological means to improve football level by using digital means, data is an inaccessible part. For example, planning training methods based on athlete kinematics data. By using athletes physiological indicators to make a diet plan. The Internet of Things, as the key infrastructure for accessing data, has increasingly been used in sports. The data monitoring system constructed by Internet of things technology has the features such as time-saving, efficient and easy to maintain.

Obviously, the Internet of Things can effectively capture the movement, energy and other data of players during a game without damaging the turf when installing ground cables. However, it should be pointed out that the Internet of Things monitoring system of football stadium is still in the development stage. Professional teams have not open their technical plans to public. Therefore, the data considered in this simulation is the data that has been processed by the embedded chip of the sensor. On this basis, how to send the data to the data center becomes a crucial problem.

Routing algorithm [5], as an important means of data transmission in the Internet of Things, has attracted extensive attention from scholars. In recent years, relevant scholars at home and abroad also have some research on routing clustering algorithm. Wang Hanming etc. [6] proposed a computer network routing optimization mode

[1] Jiyang College of Zhejiang Agriculture and Forestry University, Zhuji, Zhejiang 311800, China
[2] Yancheng Kindergarten Teachers College, Yancheng 22460, China
[3] *Corresponding author: Shaoxing University Yuanpei College, Shaoxing Zhejiang, 3120002, China

based on the improved ant colony algorithm, and optimized the pheromone concentration update and state transition rules of the traditional ant colony. Harith etc. [7] divided all events in the network into three security levels and proposed a new study on security. Robert etc. [8] proposed a scheduling algorithm for wireless nodes when limited resources, which can adapt to any scheduling in the constantly changing environment and increase the usage time of sensor batteries by 70%. Sun Long etc. [9] proposed a clustering algorithm URCC based on energy fluctuation and the number of adjacent nodes. Singh etc. [10] summarized the research on routing algorithms.

By analyzing the above research results, it can be found that when considering the communication problems of the Internet of Things, the clustering stage and the data transmission stage are the research focus. Therefore, a load-balancing Routing Algorithm for BRAFFM (Balancing Routing Algorithm For Football Match) is proposed in this paper. When the network is started, the number of cluster heads is optimized based on "adjacent rounds" to prolong the network life. Finally, by using MATLAB software to simulate BRAFFM algorithm, and the performance of BRAFFM algorithm was compared with that of LEACH, HEED and URCC. Finally demonstrate the feasibility of using wireless sensor network to collect data in football field.

II. Design of Internet of Things data monitoring system for football field

The overall technical roadmap of this design as shown in Figure 1. Collecting the data of athletes in the football field through the regular arrangement of sensors, and stored in the self-contained memory of the sensor. Then transmit the data to the data center according to the proposed Internet of Things algorithm BRAFFM algorithm proposed in this paper. Among them the BRAFFM algorithm mainly innovates in two stages: cluster head selection stage and data transmission stage. Firstly, in the sensor deployment stage, the sensor nodes are randomly distributed to improve the robustness. In the cluster head selection stage, the defined energy factor is introduced into the threshold equation to form multiple clusters. Finally, in the data transmission phase, the obtained data is sent to the base station by finding the optimal "relay" link.

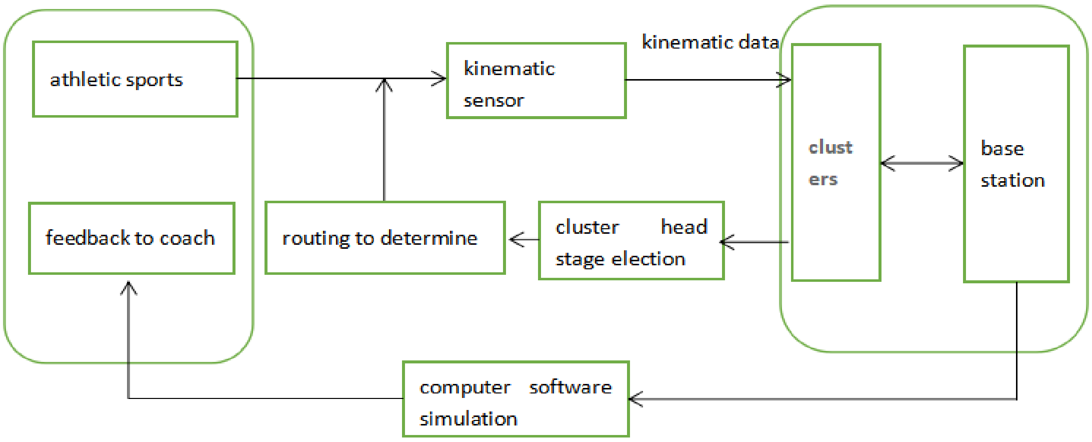

Figure 1. Overall technology roadmap

A. *Spatial analysis of football field*

A football field is a regular cuboid space, which is a regular rectangle after Two-Dimensionalization with it (overlooking). In the development process of modern sports, a large number of sports venues have adopted rectangles similar to football fields, such as basketball, tennis and swimming pools [11-13]. However, WSN faces new challenges as its application areas continue to expand and technological productivity increases. Sports fields are different from regular areas with Internet of Things monitoring systems. Carefully speaking, signal obstruction is not a major concern in conventional deployment environments (such as water). For example, if the sensor nodes are placed in water, although liquid water has a certain hindrance effect on the signal, its density is very uniform, that is, the hindrance intensity of the signal is uniform. But football fields are usually made of grass and layers of soil. Because there are gaps between grassland and soil and the appearance of gaps is random. Therefore, the installation of sports sensors in this environment needs to consider the following two issues: A) data transmission efficiency. B) Integrity of data collection.

For problem A: Compared with the preset environment of the classical routing algorithm, the obstacle for soil forming becomes the key factor restricting data transmission in the deployment under the football field. In particular, there may be huge flaws in the way data is transmitted. As we all know, the transmission mode of WSN is divided into multi-hop transmission and single-hop transmission. In the single-hop transmission network, distance is the main reason for energy consumption, and the higher density of the transmission medium in the football field increases the energy consumption. Therefore, single-hop transmission is avoided in most high-density networks.

In addition, in a multi-hop transmission network, the death of any cluster head may cause a huge impact on the network, and the ways to eliminate these effects include increasing the density and energy of the cluster head. However, the former will bring information transmission delay, the latter will increase the cost. Therefore, both single-hop and multi-hop transmissions need to be improved before they can be used in football field networks.

For problem B: Sports are often accompanied by intense confrontation. Its physical performance is high power and high frequency, that is, there is the possibility of artificial damage to the sensor.

Artificial damage is easy to cause sudden phenomenon that the classical algorithm does not take into account, that is to say, it’s easy to cause sensor sudden failure, resulting in insufficient local transmission capacity in advance. In the classical routing algorithm, data is collected from the base station (BS) in a circular pie. There is a highly selective for the route of information transmission. However, in the environment of football field, the traditional data transmission path may be interrupted due to the sudden failure of sensors. This puts forward survivability requirements for every sensor on the data path, the sudden failure of any sensor is likely to cause data loss and affect the integrity of data.

III. RELEVANT WORK AND ASSUMPTIONS

A. Sensor node assumptions

The system abstracts the football field with sports sensors into regular rectangles. Therefore, it is assumed that all sensors are arranged in this rectangular area according to random rules. All sensors can effectively cover the monitoring area without sudden failure, sensors installed according to BRAFFM algorithm have the following characteristics:

1) All sensors installed in the network have unique ID tags, and ID tags (IDS) will not be reused after the sensor fails.

2) The mounting position of the sensor moves slightly or is fixed.

3) In the case that the main switch of the monitoring network is not turned off (when the system is running), the sensor cannot replenish energy.

4) The communication channel between sensors is symmetric bidirectional channel and channel blocking is not considered.

Based on the above assumptions, it is assumed that N pcs sensors are arranged in a rectangular area of M×N according to random rules, and the data acquired by the sensors are transmitted back to the base station. Since the number of teams in a football match is the same and there is a game rule of changing the field in the first and second half, the base station (data center) installed in the center of the field is more consistent with the symmetry of data collection. After the Internet of Things data monitoring system is started, the nodes in the network have clustering behavior, forming the form of cluster head management cluster, and summarizing the data obtained by the sensors in each cluster and sending it to the base station. Adopting clustering method can effectively reduce the influence of frequent changes of network structure.

B. Energy consumption model

In wireless sensor networks, the consumed energy mainly includes data sending and receiving. Usually, according to the distance of data sent by nodes, the energy consumption of data transmitted by nodes adopts free-space energy consumption model and multi-channel attenuation model respectively, the energy consumption of each M bit data transmitted by sensors is shown in Formula 1 and Formula 2. The energy consumption of data transmission and communication between sensor nodes can be divided into two parts as a whole: One part is the energy of signal processing part of supporting equipment, which is required for circuit transmission and reception, it is considered that the energy consumption of the two is the sam, both are ME_{elec} . The other part is the energy consumption of the RF power amplifier during data transmission of the sensor node, which accounts for a large proportion of the energy consumption of the sensor node, within a certain communication distance, the energy consumption is $E_{amp} \times M \times d^2$, if beyond this range, the energy consumption increases greatly and becomes $ME_{amp}d^4$.

$$E_R(M) = ME_{elec} \tag{1}$$

$$E_T(M,d) = ME_{elec} + ME_{amp}d^{\tau} \tag{2}$$

The path loss factor τ is related to the transmission distance, and the transmission distance threshold is set as d_0, if $d < d_0$, $\tau = 2$, if $d > d_0$, $\tau = 4$.

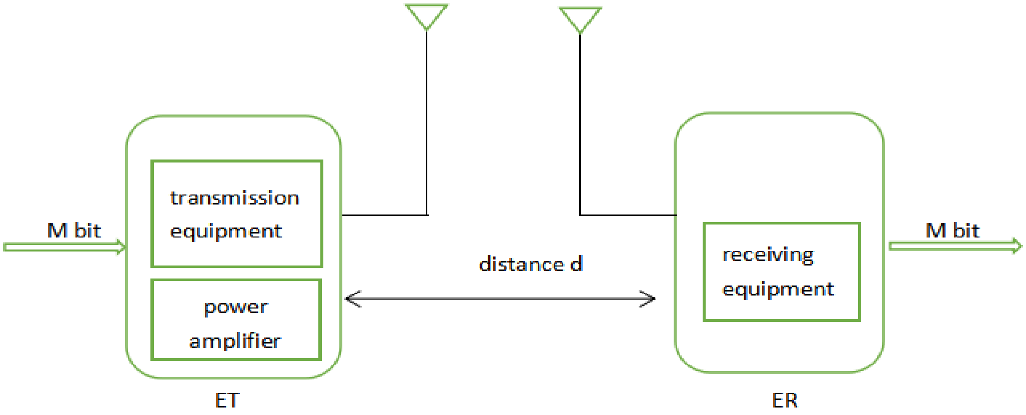

Figure 2. Energy consumption model

IV. CLASSICAL ALGORITHMS MATCHING ANALYSIS

A. Classical algorithms disadvantage

LEACH is a low-power self-adaptive cluster-layered protocol [14], which is the most classical routing algorithm. It reduce energy consumption effectively by using the clustering method. However, its clustering rules have great defects in the matching of the Internet of Things data monitoring algorithm in football field. It mainly focuses on the following aspects:

1) Cluster head selection stage:

In LEACH algorithm, cluster head generation adopts random mechanism, as shown in Formula 3. In LEACH algorithm, each sensor node randomly selects a value between 0 and 1. Calculate $T(n)$, if this number is less than the threshold $T(n)$, the node becomes the cluster head of the current round.

$$T(n) = \frac{p}{1 - p(r \bmod \frac{1}{p})} \tag{3}$$

Among them, P is the percentage of the expected number of cluster heads in all nodes, r is the election rounds number, $r \bmod \frac{1}{p}$ representing the number of nodes with cluster heads elected in this cycle, and G is the set of nodes with cluster heads not elected in this cycle.

This ensures that each node in the network has a considerable probability of becoming the cluster head. The function is to ensure that the energy consumption rate of all cluster heads is in a relatively balanced state. However, if the single fairness scheme is adopted in football field, it is easy to cause the problem of cluster size. In addition, football players in different positions have different technical characteristics, and there are huge differences in the way of working on the sensor. That is to say, the data output of different regions exist big differences. Therefore, the clustering task cannot be performed using the above single formula.

2) Data transmission stage:

In LEACH algorithm, after receiving the application instructions of all non-cluster-head nodes, the cluster head creates the corresponding scheduling table according to the number of sensors in its cluster and establishes the scheduling sequence. Then the cluster head sends the data directly to the base station. However, in football, the high-intensity confrontation of players may cause the sudden failure of some sensors. In the monitoring system, the performance is partial paralysis, that is the local data transmission is not smooth. Therefore, the rules of data transmission need to be improved to make it have certain redundancy.

V. BRAFFM ALGORITHM

In BRAFFM algorithm, the selection stage of cluster head usually consists of several parts. Before the algorithm is officially started, all the sensors are in full power state, and the state of all the sensors is the initial energy state by default. The energy state of a sensor is represented by form $A(i,r)$. The classical concept of "round" is introduced into this algorithm. Where I represents the unique identification of the sensor. R is the number of rounds, $r_{\max}$ is the preset maximum cycle and $r \in (1, r_{\max})$. Therefore, the fully charged state of a sensor can be written as $A(i, start)$. In the field of wireless sensing, energy is an important indicator to measure the health of sensors. Therefore, $\ln \frac{A(i,r)}{A(i,start)}$ indicates the health degree of a sensor at a certain time, defined as energy factor. It is easy to know that with the continuous progress of monitoring system data collection tasks, this parameter presents a continuous downward trend on the time axis, and its range is $(-\infty, 0]$. When its value is 0, it means that the sensor is in the healthiest state. When the range curve keeps decreasing, it means that the loss of the sensor is increasing.

A. Cluster head generation algorithm

In routing algorithms, the generation of cluster heads needs constant competition and replacement. In the initial stage of competition, the base station [15] sends the initial signal to the whole monitoring area in the form of radiation. Each sensor node enters the preparation stage of cluster head election. The BRAFFM algorithm proposed in this paper is based on the classical routing algorithm and combined with the actual situation of football match, proposed a cluster head generation algorithm suitable for football match. The specific process is as follows:

First, after the base station broadcasts network turns on the "HELLO" message, and each sensor receives the message and waits for entering work status. When all sensors are activated, the BCAFFM algorithm enters the first stage, that is the cluster head generation stage. When the cluster head is elected, the sensor in each network will spontaneously generate a random number rand, and the value of the random number is in the range of $(0,1)$, and this value is compared with the threshold function to determine the final selection of cluster head.

Therefore, the rand generated in this paper is compared with the new threshold function $T^*(i)$. The reason lies in: the classical algorithm performs the data transmission task under the condition that the whole network changes in a balanced rhythm according to the set rules. However, it is very difficult to achieve a balanced rhythm in football matches because of its tactics and the requirements of physical distribution of football players. For example, during the execution of a certain tactic (including attack or defense), the two teams will reduce their attack and defense intensity, that is, after the attack and defense round, the two teams will return to the "formation" state, reduce the intensity of the game, and seek the next attack opportunity. In other words, in the monitoring of football matches, the monitoring cycle triggered by sensors has peak-valley changes.

Therefore, this algorithm considers that the cluster head requirements of the football field data monitoring system for "adjacent round" are different. Therefore, a new threshold function formula $T^*(i)$ based on "adjacent wheel" is proposed. $T^*(i)$ use the energy defined above as shown in formula 4.

$$T^*(i) = \begin{cases} \dfrac{p}{1 - p \times (r \bmod \frac{1}{p})} \times \square & r \in [1, r_{\max}] \\ 0 & other \end{cases} \tag{4}$$

The calculation logic of $\square$ is shown in Formula 5.

$$\square = \begin{cases} 1 + \dfrac{r}{r_{\max}} + \ln\dfrac{A(i,r)}{A(i,start)} & r = 2k+1 \\ 1 - \dfrac{r}{r_{\max}} + \ln\dfrac{A(i,r)}{A(i,start)} & r = 2k \\ 1 & r = 1 \end{cases} \tag{5}$$

Among them, p is the percentage of the expected number of cluster heads among all nodes, r is the number of rounds, $p \times (r \bmod \frac{1}{p})$ representing the number of nodes with cluster heads elected in round R, and G is the integer of $k > 0$ the set of nodes with cluster heads not elected. It can be seen from the formula that the selection of cluster heads with different sizes of "adjacent round" can better match the triggering frequency of the sensor caused by football, making the formation of cluster heads and cluster members more reasonable. After all the cluster members join in the cluster, the cluster head assigns tasks to each sensor according to the TDMA time slot table.

B. Routing determine

Energy consumption is the most urgent problem in data transmission. At present, the choice of data transmission mode mainly focuses on two aspects (single-hop transmission and multi-hop transmission). Among them, single-hop transmission means that the cluster head sends the collected data directly to the base station.This method is simple to implement, but its disadvantages are also very obvious. Due to adopt the communication way that cluster head contact with base station directly. Distance has great influence on energy consumption, and energy consumption at different distances has significant difference. In football, sensors near the sidelines face their toughest test of energy. Multi-hop transmission can effectively solve the problem of edge sensor energy consumption too fast. There should be no interruption during the relay. However, the difficulty of multi-hop transmission is how to ensure the continuity of data relay process. Especially players trample in the football match, and so on, putting forward higher requirement for the reliability of multi-hop transmission link.

This chapter proposes a multi-hop algorithm suitable for data transmission in football matches. In multi-hop transmission, it is assumed that the cluster head performing "relay" only forwards information from the previous cluster head and does not perform other "relay" tasks. Then the problem of the base stations that transmit data from the sideline or other parts of the pitch can be translated into the choice problem of "relay" links.

In order to select the appropriate link. Remember the cluster head group is $K = \{K_1, K_2 ......\}$, the cluster head K_n needs to find K_{n+1}, K_{n+2} ,... K_m Etc as the next "relay" cluster head. Search for at least one relay cluster head during one data transmission. Then, the total transmission distance of data in the link is shown in Formula 6.

$$\begin{cases} E_{K_i} < \dfrac{E_{K_{i+1}} + E_{K_{i+2}} + \cdots\cdots + E_{K_m}}{m-i} \\ d_{SUM} = d^2(K_i, K_{i+1}) + \cdots\cdots + d^2(K_{i+x}, K_{i+x+1}) \end{cases} \tag{6}$$

Among them, E_{K_i} is the energy of cluster head, d_{SUM} is the total transmission distance, $d^2(K_i, K_{i+1})$ is the transmission distance of a "relay" interval, x is the number of "relay".

In the routing transmission node, when the energy of the current cluster head is less than the later average energy of the cluster head that can select "relay", the cluster head selects the nearest cluster head as the "relay" cluster head of the next level, and repeats the process successively. Until the remaining energy of the current cluster head is greater than the average energy of subsequent cluster heads, the cluster head directly sends the data to the base station.

VI. SIMULATION AND ANALYSIS

A. Simulation Parameter Setting

Experimental simulation adopting MATLAB software as a simulation tool, simulation scene data is taken from the premier League official stadium size. According to the algorithm proposed in this paper, require to set 100 nodes, and the base station node is located at the geometric center of the target area (52.5m,34m). The specific parameter values are shown in Table 1 below.

Table 1. Experimental simulation parameters

Parameter	value
The base station location	(52.5,34)
Node number	100
Power consumption for sending and receiving messages	50 nJ/bit
Power consumption of short distance transmission amplifier	10 pJ/(bit·m2)
Power consumption of long distance transmission amplifier	0.013 pJ/(bit·m2)
Packet length	4000 bit
Initial sensor energy	0.5 J
The simulation area	106×68

B. Simulation result analysis

In this paper, performance parameters such as network stability period, base station acceptance of data packets and total network energy consumption are selected for simulation verification. This paper selects three algorithms such as LEACH, HEED and URCC for comparison and verification with Proposed Algorithm in this paper.

1) Network stability period comparison

Figure 3 is the comparison for the viability of the four algorithms. The stability period of network is the most important problem to be considered in the design of monitoring system. It is the basic requirement of an algorithm, and only when the algorithm has sufficient lifetime can improve the other performance indicators. Figure X shows the network lifetime through the sensor failure rate over the same time span. It can be seen from Figure 3 that the algorithm proposed in this paper has a strong life cycle. Under the same time(x-coordinate) and same situation, the sensor failure rate of the proposed algorithm in this paper is kept at 10%. At the same time, all the LEACH sensors of the classical algorithm have failed, and nearly 60% of the networks of HEED and URCC algorithms have been damaged. The results show that the proposed algorithm in this paper is significantly longer than LEACH, HEED and URCC in network life cycle.

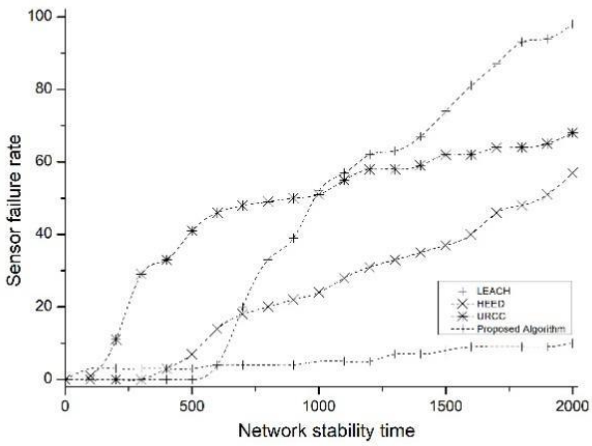

Figure 3. Network stability time

2) Comparison of total network energy consumption

Another key factor in energy evaluation of Internet of Things system is also the object that this paper focuses on when designing algorithm. In order to quantify the energy comparison in the running process of the algorithm, this paper adopts the total energy consumption of the network in the same time as the energy evaluation index. We compared and analyzed the network energy consumption of this algorithm with other three algorithms. The simulation results are shown in Figure 4. It can be seen from Figure 4 that in the initial stage of network operation (within 1000), the energy consumption slopes of LEACH, HEDD and URCC algorithms are similar. This indicates that the three algorithms have similar relative energy consumption rates in this stage. In contrast, the algorithm proposed in this paper has an obvious "slow" slope at this stage, that is, the algorithm proposed in this paper well controls the energy consumption at the initial stage of the network. By observing the ordinate in the figure, it can be seen that the algorithm proposed in this paper has a longer energy consumption time. With the continuous operation of the network, the network energy of LEACH, HEDD and URCC is exhausted in 2200, 2600 and 3500 rounds successively, while the network of this algorithm stops until 4000 rounds.

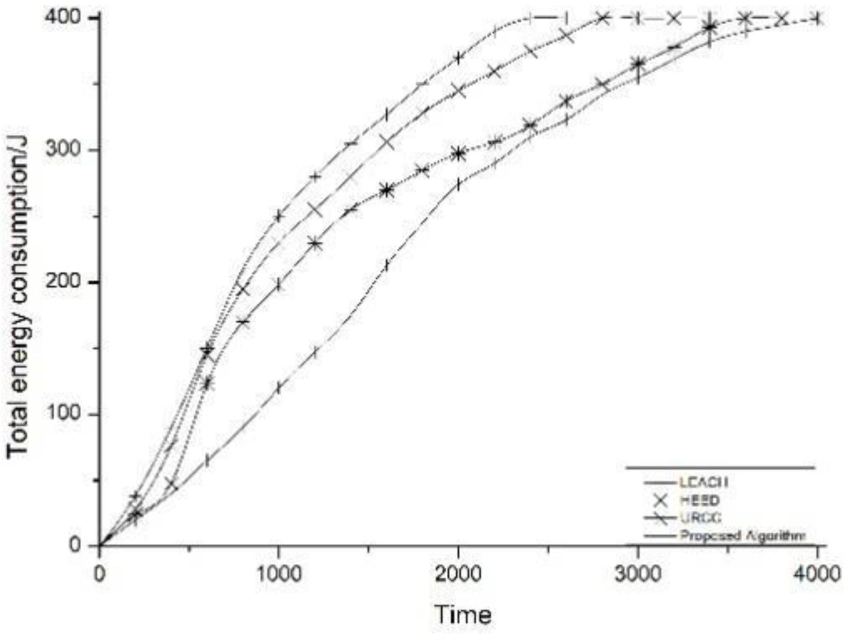

Figure 4. Comparison of network energy consumption

3) Network data carrying capacity analysis

In addition to the network stability period and energy, data transmission capability is also a non-negligible performance index of routing algorithms. In order to verify the data carrying capacity of the proposed algorithm. In this paper selects the amount of data received by the base station in the same time as the evaluation means of the data throughput of the algorithm. The specific statistical results are shown in Figure 5. It can be seen from Figure 5 that the base station receives a small amount of data when running the network of LEACH and HEED algorithm. As the LEACH algorithm is running, the sensor that adopts single-hop transmission mode may become invalid over time, resulting in data "vacuum" in some monitoring areas. For HEED algorithm, due to the link interruption, the link distance of network reconstruction is too long, which increases the difficulty of data transmission. URCC algorithm had low data transmission efficiency for a long time, and did not surpass LEACH and HEED until after 1250 rounds. However, from beginning to end, the proposed algorithm always outperforms the other three protocols in data throughput. It is 1.5-2 times of the other three protocols.

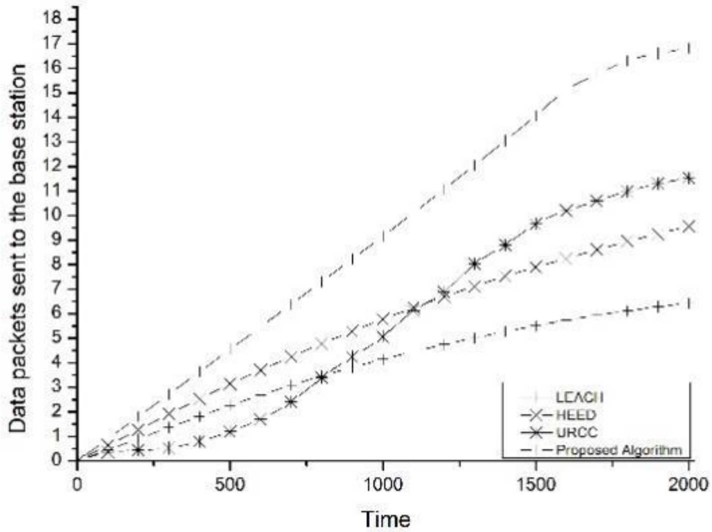

Figure 5. Network data carrying capacity

VII. Conclusion and prospect

At present, it shows homogenization trend aim at the research of football technique and tactics in all countries in the world, this paper analyzes the characteristics of modern football and preliminarily analyzes the possibility and necessity of establishing the football field data monitoring system development. This paper simulates the performance of the data monitoring network and its matching with the football field by computer software. Through the computer algorithm achieving efficient collection for the data of athletes on the fields during the process of competition, providing more accurate data for tactical design and providing new ideas for athletes training planning. The focus of the author's research in the next stage is to discover the potential technical advantages and defects of players through the data obtained from the training of AI artificial intelligence algorithm, and use this data to assist the improvement of players' ability and help them getting comprehensive improvement in physiology, kinematics, techniques and tactics. Expecting to make a positive contribution to China's football project enter into the world.

References

[1] Ma Li. The present status and promotion strategy of China's national soft power[J]. Science Tribune, Science Herald, 2015.

[2] Ma Ling. The new development of traditional national sports from the perspective of cultural soft power--comment<Research on the Institutional Guarantee of national Cultural Soft power and the development of national traditional Sports>[J]. Journal of The Chinese Society of Education, 2018.

[3] Xu Jinshan, Chen Xiaoke, Shen Jianhua, etc. Research on the introduction of foreign players and the development of Chinese professional football[J]. Journal of Beijing Eniversity of Physical Education, 2006, 29(002):159-161.

[4] The physiological and technical characteristics of ability Li Mingjie. Brief talk physiological and technical characteristics of visual field ability in football[J]. Tomorrow, 2019(7):0011-0011.

[5] Younis A M . A survey on routing protocols for wireless sensor networks[J]. Ad Hoc Networks, 2005.

[6] Wang Hanming. Improved ant colony algorithm in computer network routing simulation research[J]. Electronic test, 2020(17):40-41+124.

[7] Harith, Fakhrey, Martin, etc. The Optimum Design of Location-Dependent Key Management Protocol for a Multiple Sink WSN Using a Random Selected Cell Reporter[J]. IEEE Sensors Journal, 2018.

[8] Roberto R Z, Ramiro U , Elena R , etc. An Adaptive Scheduler for Real-Time Operating Systems to Extend WSN Nodes Lifetime[J]. Wireless Communications and Mobile Computing, 2018, 2018:1-10.

[9] Sun Long, Xu dingrong, Ma Fei. A new non-uniform clustering routing protocol for WSN based on chain cluster[J].Computer applications and software, 2015,32(01):106-109.

[10] Singh S, Kumar P , Singh J . A Survey on Successors of LEACH Protocol[J]. IEEE Access, 2017:4298-4328.

[11] C. M. Pereira, T. V. Heitor, A. Heylighen. Improving Pool Design: Interviewing Physically Impaired Architects[C]// Cambridge Workshop on Universal Access & Assistive Technology. Springer, Cham, 2018.

[12] Guo Y. Architectural analysis and design of urban planning exhibition hall based on four design elements[J]. IOP Conference Series: Earth and Environmental Science, 2019.

[13] Lei G, Xiaoming L U , Mingyu L I . The Research and Design of the Tennis Court in Wuhan Optics Valley International Tennis Center[J]. New Architecture, 2019.

[14] Heinzelman, W. Chandrakasan, A. Balakrishnan, H. An application-specific protocol architecture for wireless microsensor networks. IEEE Trans. Wirel. Commun 2002, 1, 660–670.

[15] Marzetta T L. Noncooperative Cellular Wireless with Unlimited Numbers of Base Station Antennas[J]. IEEE Transactions on Wireless Communications, 2010, 9(11):3590-3600.