IEEE Access
Multidisciplinary | Rapid Review | Open Access Journal

SPECIAL SECTION ON ROADMAP TO 5G: RISING TO THE CHALLENGE

Received December 30, 2018, accepted January 12, 2019, date of publication January 22, 2019, date of current version February 27, 2019.

Digital Object Identifier 10.1109/ACCESS.2019.2894129

Research on Key Technologies of Smart Campus Teaching Platform Based on 5G Network

XIN XU[1,2], DAN LI[2], MENGYAO SUN[2], SHICHAO YANG[2], SHUJIANG YU[1], GUNASEKARAN MANOGARAN[3], GEORGE MASTORAKIS[4], AND CONSTANDINOS X. MAVROMOUSTAKIS[5]

[1]School of Economics and Management, Hebei University of Technology, Tianjin 300130, China
[2]North China University of Science and Technology, Tangshan 063210, China
[3]University of California at Davis, Davis, CA 95616 USA
[4]Department of Business Administration, Technological Educational Institute of Crete, 72100 Heraklion, Greece
[5]Department of Computer Science, University of Nicosia, 1700 Nicosia, Cyprus

Corresponding author: Shujiang Yu (mbaysj@163.com)

ABSTRACT With the development of mobile Internet technology and the popularity of intelligent mobile terminals, the data traffic load of mobile client users on the smart campus network platform has surged. How to reduce the data traffic of the smart campus network platform is an urgent problem to be solved. First, this paper discussed the key technologies of smart campus network teaching platform under the background of the 5G network, expounded the critical technologies of the transport layer of the Internet of Things (IoT) technology, and analyzed from the development perspective of the IoT platform. Second, by investigating the online classroom data of five types of colleges and universities in China and comparing the advantages and disadvantages of online classroom teaching and traditional classroom teaching, it is found that the number of online courses in colleges and universities has exploded in the second half of 2017. Next, this paper analyzed the demand of smart campus online teaching platform under the background of the 5G network, thus established an online teaching platform based on the four initiatives operation model (government-led, college sponsor, teacher subject, and academic director). Finally, this paper adopted the improved VIRE localization algorithm to obtain the specific location information of the student users in the classroom and, then, compared with the error obtained by the VIRE algorithm, and the error of the improved VIRE algorithm is smaller. In the process of obtaining information, the 5G network technology is used for data transmission, which can shorten the check-in time and can improve the positioning accuracy.

INDEX TERMS 5G network, smart campus, online teaching platform, improved VIRE location algorithm.

I. INTRODUCTION

Along with the development of the Internet of Things technology, due to the limitation of network transmission mode, the existing 4G LTE system can no longer meet the demands of different clients for information transmission rate owing to the single scenario of the IoT. 5G network arises at the historic moment and changes qualitatively in three aspects: data transmission rate, number of connected devices and time delay [1]. 5G network will alter the previous transmission mode, enrich communication between users-devices as well as devices-devices, apply to complex IoT applications, thus to achieve seamless communication in 5G era [2].

As the prototype of a small society, the Internet of Things framework of Smart Campus is also complicated, hence the popularity of IoT is still low at this stage. This paper aims to provide direction for 5G network to be applied in the construction of Smart Campus, and develop the maximum application of smart phone on campus. The most typical application form of traditional Smart Campus is the application of network teaching platform, which connects teachers and students, helps to enrich students' learning resources and improves teachers' teaching performance [3]. The construction of Smart Campus is not just a single trend, it needs to be closely combined with the improvement of education technology and education resource informatization [4]. Many experts and scholars at home and abroad began to study the construction of Smart Campus: Xia *et al.* [5] proposed a Smart Campus framework based on Internet of Things and cloud computing that integrating hardware resources through virtualization technologies. The planning and recommendation of Smart Campus model for teaching resources proposed by an Indian research institute made reasonable use of school

teaching resources and improved the teaching quality [6]. The University of California has realized intelligent control on the campus hardware facilities, making it possible to monitor the campus environment [7].

In view of the pain spot of students' sign-in during the teaching process, this study envisaged in combination with 5G network and mobile terminal to achieve more accurate information of students' sign-in in class, studied whether the network teaching platform of Four Initiatives model could be better applied under the background of 5G network. It intends to discuss the accuracy of student sign-in information by improving VIRE location algorithm to obtain the specific location information of the sign-in users in class.

II. THE OVERALL FRAMEWORK OF SMART CAMPUS BASED ON 5G NETWORK

A. KEY TECHNOLOGY ANALYSIS OF INTERNET OF THINGS TRANSPORT LAYER

The wide application of network teaching platform is based on the development of Internet of Things technology. IoT framework mainly consists of perception layer, network layer, common technology layer and application layer. From the perspective of IoT platform development, the wireless network layer is the core technology for device terminal and the cloud of IoT. At present, the relatively mature IoT framework network layer is mainly composed of IoT devices, IoT gateways and IoT cloud. Devices such as Wifi, GPRS, 3G/4G/5G, etc., supports TCP/IP by its very nature, thus making it possible to apply directly to IoT network layer. However, devices such as Zigbee, Bluetooth, etc., are not originally support IP protocol, and it requires gateways(protocol conversion) to be involved in the IoT transport layer. Therefore, for bluetooth devices in the perception layer, mobile phones act as gateways.

The common typical application of IoT network layer in daily life is that the mobile phone communicates through its own blue-tooth and peripheral blue-tooth devices, and the perception layer information can be exchanged with cloud server through Wifi or 3G/4G/5G module. Communication mode are shown in figure 1.

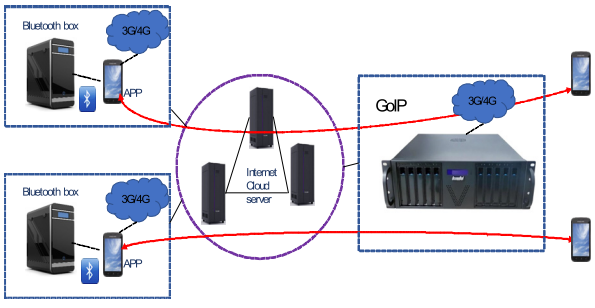

FIGURE 1. Communication mode between perception layer and the cloud.

The features of information transmission of IoT can be explained from two aspects. In one aspect, mobile terminal, mobile phone and PC are the most direct access to IoT, so the core component of IoT transmission are: device end-gateway-cloud-user end. In other aspect, analyzed from the application developing technology perspective, major application of IoT mainly built on the bases of TCP/IP framework, accordingly without considering the relatively lower level gateway protocol, the primary component of IoT transmission are: device end-remote end-user end.

As a result, for the purpose of service level improvement the of IoT for human beings, it can be analyzed from the perspective of improving the information throughput rate.

B. TECHNOLOGY ADVANCEMENT

1) TECHNICAL PRINCIPLES OF 5G NETWORK

Currently, network communication mainly uses electromagnetic waves to carry. Different frequency of electromagnetic wave leads to various transmission speed of information, of which the characteristic is: the higher the frequency, the higher the signal transmission bandwidth is, thus the higher the information transmission rate is. At present, the commonly used communication bands are all in the low-frequency stage with good stability, but the low-frequency band resources are limited, while 5G technology uses high-frequency band, which not merely improves the information transmission rate, also makes use of the idle high-frequency band resources at the same time.

2) ADVANTAGES OF 5G NETWORK

According to related literature [8], the differences between 5G network communication technology and 4G mainly lies in the number of transmission rate, time delay, connections and mobility, etc.

TABLE 1. Comparison of two network transmission models.

	Rate	Time Delay	Connection	Mobility	Transmission path
4G	100Mbps	30-50ms	10,000	350KM/h	Base Transceiver
5G	10Gbps	1ms	1,000,000	500KM/h	Direct transmission between devices
Gap	Increased 100 times	Reduced 30-50 times	Increased 100 times	Increased 1.5 times	No Base Station

According to the comparison result in table 1, the transmission rate of 5G network is 100 times faster than that of 4G, and the response delay of 1ms is 30-50 times shorter than that of 4G. In view of electromagnetic wave frequency band, 5G utilizes high frequency band to solve the problem of resource shortage in low-frequency stage. Moreover, according to the analysis of electromagnetic wave transmission mode, 5G network communicates directly among devices, reducing the cost of building base stations.

In addition to the advantages listed in the above table, the 5G network also features high reliability and low power consumption, allowing a variety of IoT devices to access.

For instance, it can satisfy the needs of car networking, industrial control and automatic drive, of which the time delay is required to be as low as 1ms, whereas protocols such as authentication and encryption processes for Wifi/4G network do not take into account communication requirements of ultra-high reliability and low latency, etc.

C. IoT FRAMEWORK MODEL OF SMART CAMPUS

Smart class is a key aspect of the application of IoT in Smart Campus. Based on the studies of IoT technology towards methods in the teaching process from universities and colleges, it has become their focus and hot-spot of teaching and research. The so-called smart class aims to improve the efficiency of traditional teaching and teacher-student interactions in class through information collection equipment, mobile terminals, PC terminals and other IoT devices via big data, cloud computing, IoT technology, etc.

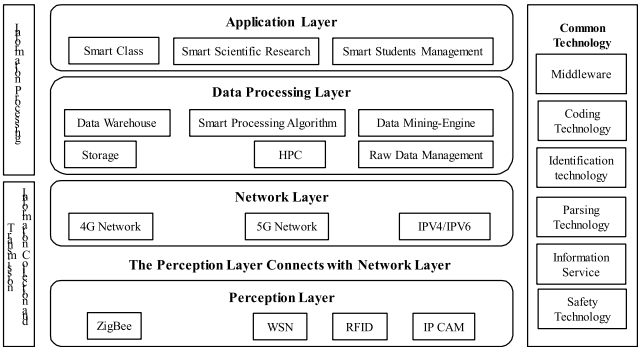

FIGURE 2. Framework model of smart campus IoT.

Smart Campus IoT framework system contains information transmission between human and devices, from devices to human, and among devices. The transmission of information between devices can be achieved by human intervention and the information transmitted to the processing layer can be fed back to the application layer to realize the application of IoT devices and teaching purposes. This framework system consists four layers: perception layer, network layer, processing layer and application layer. The framework model is shown in figure 2. The steady and rapid application of IoT should be guaranteed by common technique.

- **Perception Layer:** The main role of the perception layer is to accurately and rapidly identify some node information. For example, the recognition of identity information of teachers, of students who come to attend the class, lesson information, participation, etc. with the application of sensing device, infrared sensor device, cameras and other devices.
- **Network Layer:** Network transmission mode makes an essential part of the application of IoT platform. Stability, rapidity, accuracy and other aspects of network transmission are able to guarantee the real-time collection and transmission of all kinds of information in Smart Campus as well as bring better user experience.

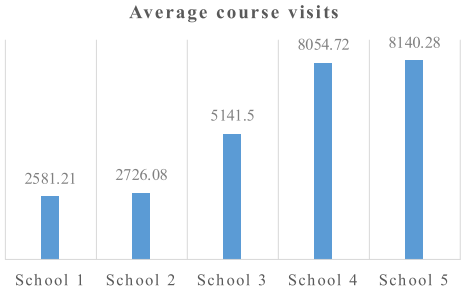

FIGURE 3. Variation diagram of courses number.

- **Processing Layer:** Gathering the data of various user activities, business and interactions in the perception layer to build support of comprehensive data Smart Campus; Integrating technologies such as raw data management, intelligent algorithm and data-mining engine to realize efficient and scientific data cloud computing services and provides scientific storage and computing support for Smart Campus.
- **Application Layer:** The functions of application layer are mainly embodied in three aspects: users' application of Smart Campus informatization, managerial decision for students' learning, and social information services. Among which, managerial decision is higher-level application. For example, information elimination of equipment failure, teaching performance evaluation, analysis of students' learning effect, disciplines and departments analysis.

III. ONLINE CLASS OF COLLEGES AND UNIRERSITYIES

Human beings has entered into the information age. Information industry is developing at fast speed and promoting the progress of all walks of life. Under this situation, multimedia network teaching in the education field is emerging as an important form of teaching. It is the product of the application of multimedia and network technologies in teaching, also a way for multimedia teaching to make full use of the network for communication [9]. The emergence of multimedia network teaching has brought new approaches and methods to school's audio-visual education programme, which will enrich the education form of school teaching model and make it more advanced. In the information society, the teaching model under the network multimedia environment turns into the dominant teaching model [10], [11]. Currently, many schools are carrying out network construction. Based on the new teaching model formed by the network environment, they makes use of the unlimited information resources online, breaks through the constraint of multimedia teaching on the resources, distance and scale, and pushes it to the network multimedia teaching. The appearance of global classroom is the most representative of this trend. Global classroom uses wide area computer network connecting a large number of universities around the world to carry out teaching activities. At present, there are many universities in developed

countries are conducting teaching activities in this field, and it is constantly expanding. Therefore, the globalization of multimedia network is the inevitable trend of network development [10], [12], [13].

The teaching model of ''the students as main body, teachers as leadership'' (Two-Way Model) for online class is the outcome of this era combined multimedia technology, network communication technology and other information technologies with modern education theory. In recent years, constructivism, an important branch of cognitive learning theory, has been gradually prevailing in the west countries. Due to various characteristics of multimedia network communication technology, it is particularly suitable for the realization of constructivism learning environment. In other words, multimedia network communication technology can be applied as an ideal cognitive tool in the constructivism learning environment, so as to better promote cognitive development of students.

A. OVERVIEW OF ONLINE CLASS TEACHING MODEL

The teaching model of ''the students as main body, teachers as leadership'' for online class refers to a new teaching model that helps students to carry out active learning. Teachers, being resource organizers and participants, their leading role is equally important. They should not only organize learning resources from the perspective of students, but also instruct students how to learn. Other than guiding students to learn independently in class and imparting professional knowledge and skills, teachers also offer students help with the knowledge and skills they mastered in their own discipline or even outside the discipline after class [14].

It is generally believed that traditional teaching model consists of teachers, students, teaching process as well as teaching media. The elements of teaching model of ''the students as main body, teachers as leadership'' for online class are composed of students, resources, teachers and the environment. Here, resources and environment need to be explained. Resources are those in online class, which refers to all the teaching resources that can be integrated in the teaching platform constructed in online class. There are two meanings as to the environment: one is the information environment, including the hardware such as multimedia computing online class and teaching software, network resource software. Second, it refers to a democratic, open and equal learning environment.

In the teaching model of ''the students as main body, teachers as leadership'' for online class, students are the center in learning process, and teachers are the designers and instructors of teaching. The teaching objectives of teachers are most conspicuous in the following regard: first, to promote the allround development of students' discipline knowledge, skills and abilities. Second, to enhance students' cognitive ability, especially the ability to control information, which includes the ability to obtain, process, utilize and exchange information. Third, to stimulate the development of students' personality, including their emotions, attitudes and characters. This new teaching model can both give full play to the leading role of teachers and make students' learning space and contents more open, so that students at different levels can actively participate in learning, fully reflecting the dominant position of students.

Constructivism learning theory laid the theoretical foundations for the ''the students as main body, teachers as leadership'' teaching model. This new model emphasizes conducting teaching in the network environment with rich learning resources, always taking students as the main body, and highlighting the consciousness of students' active learning and the ability of independent learning. Construction of Two-Way model requires understanding of its connotation in the first place, which is the whole process of instructing teachers' teaching process and the design, development, evaluation and management of teaching resources with the goal of cultivating students' learning initiative.

The learning strategies adopted by Two-Way model are mainly about exploration on learning methods and problem-solving methods. Under the guidance of teachers, with the help of a variety of rich learning resources, students could discover new knowledge, summarize rules by discovering problems, exploring information and solving problems, thus to achieve meaning construction. In this students-centered teaching model, in order to achieve learning goals, students will try various approaches and meet all sorts of difficulties. Therefore teachers should bring into full play to their leading role, give support and encouragement, and help them find solutions.

In the Two-Way model, teachers' evaluation and students' self-evaluation are combined together, which exerts positive effects of diagnose and incentive function of the evaluation. The results of evaluation should not be considered as merely the score of a test, but should stress the informatization, intelligence and individualization of evaluation. Informatization refers to the assessment of students' information ability. Intelligence evaluation means improving the computer's ability to respond to students' deep-seated problems, such as learning progress monitoring and student achievement management. Individualization is aimed at promoting the development of each student's zone of proximal development(ZPD) while giving corresponding evaluation according to the individual's different learning progress and outcome.

B. CHARACTERISTICS AND ADVANTAGES OF ONLINE CLASS TEACHING MODEL

Two-Way model is a new teaching model that aroused people's research interests after the 1990s due to the application of constructivism learning theory in education technology and the progress of network multimedia technology. This model regards students as the main body and teachers as leadership, both are of considerable importance in teaching. With the rise and evolution of network multimedia and the establishment of global knowledge network, increasingly attention has been paid to the Two-Way model.

Two-Way model is featured by flexibility and Pro-activity. Flexibility is mainly reflected in the teaching process: regarding the same problem, students, as main body of learning, can adjust and choose materials they consider valuable and select suitable research methods to study and solve the problem in line with their own learning style, interests and level of capacity. Teachers in the leading position can flexibly organize valuable teaching resources by their own teaching styles and abilities [15]. Pro-activity is reflected in the process of learning that teachers can actively control the process and guide students to actively study simultaneously. During the learning process, students can take the initiative to command the process and learning pace, and cultivate their information and cultural skills by searching and using relevant resources and materials provided by teachers. Comparison between Two-Way model and traditional teaching model are as follows (Table 2):

TABLE 2. Comparison between two-way model and traditional teaching model.

	Traditional Teaching Model	Two-Way Model
Attributes of teaching material	Static central position	Dynamic A kind of learning resources
Teaching structure	Emphasize linearity	Linear and Nonlinear Emphasize students
Teaching methods	Concert action	Concert and independent action
Scope of learning content	Limited	Unlimited connection
Stability of learning content	Opinions of one person or certain group tend to be outdated	Dynamically update and synthesize views in this field
Communication form of learning	Single point is the weak ability on man-machine interaction synchronous communication	Computer-mediated interactive synchronous and asynchronous communication
Role of teachers	Initiator of dominate knowledge	Promoter, helper and coordinator of the construction of knowledge meaning
Students learning	passive acceptance	Active learning, active meaning construction
Role of teaching media	Presentation tools assisting teaching	Cognitive tools promoting students learning
Teaching evaluation	Students are evaluated by correct answers. It emphasizing structure and adopting quantitative analysis	Conduct mufti-evaluation through tests and students' work, lab reports and learning abilities, etc. Process is equally important as the results。 Quantitative and qualitative analysis are adopted for evaluation.

It can be seen that Two-Way Model in online class not only emphasizes the excellent and rich learning resources provided by teachers, but also the inquiry and creativity of students' learning process, the autonomy of learning, and the comprehensiveness and consistency of learning design.

As can be seen from the figure above, online classroom teaching will give students more opportunities to contact the classroom, which is more popular with students than traditional classroom teaching.

C. TEACHING SITUATION ON ONLINE CLASS

In order to study the teaching situation of online class, this paper investigated the usage data of online class from five universities in China, and obtained their opening time and number of online courses. Figure 4 is the variation diagram of courses number.

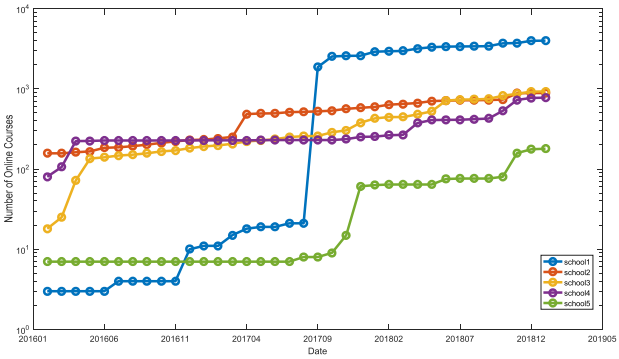

FIGURE 4. Variation diagram of courses number.

As we can seen from table 4, since the end of 2016, colleges and universities have started to offer their own online teaching courses, and in the second half of 2017, the explosive growth shows that the demand for online class is a vast upsurge. It shows that the demand for online teaching courses is very extensive. By June 2018, the number of online teaching courses in five schools has gradually stabilized. This is the result of 4G limitations. It is conceivable that with the combination of 5G network technology and online teaching platform, the number of online teaching courses will further increase. In this case, combining 5G network technology with network teaching platform will greatly improve education level.

One of the development trends of education in the 21th century is the informatization and digitization of education. The network teaching platform is an vital embodiment and component of the digitization construction of colleges and universities. To build a mature and complete digital campus, it is necessary not only to provide complete hardware facilities, but also to effectively use these facilities in the existing information technology environment, so as to integrate them into teachers' daily teaching work and students' independent learning process. Network teaching platform is a microcosm of college informatization, a system platform integrating teaching, management and service. It not merely offers technical support for students' course selection and teachers' evaluation, but also provides a good environment and platform for the communication and interaction between teachers' auxiliary teaching and students' independent learning.

Some scholars started with main users of network teaching platform—students, to investigate their participation situation. According to the survey, students' emotional

participation in the use of network teaching platform is relatively positive, but the level of behavioral and cognitive involvement is not high. The reason for low behavioral participation mainly on account of a lack of strong guidance and management of the network teaching platform and teachers, while the major reason for low cognitive involvement is the lack of awareness and ability of students to consciously use network learning strategies.

In a research that investigated the promotion and application of education technology in colleges and universities within wide range, the author, combining innovative promotion theories together with the actual situation of education informatization, proposed the Four Initiatives operation model (Government-led, University-sponsored, Teacher-centered, and Academically competent four-in-one efficient organic operating system) constructed and implemented in the application and popularization of education technology in local colleges and universities, as is shown in figure 5.

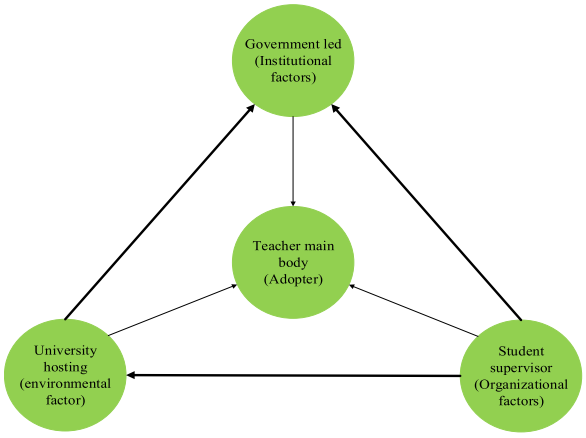

FIGURE 5. Four initiatives diagram.

This model incorporates a number of key influencing factors in the promotion of educational technology, element one: the government. The government is the senior management of universities and the majority of front-line teachers. The government's policy support and orientation play an important role in the promotion and application of educational technology. We categorize this kind of support promotion as the institutional factor in the application mechanism of educational technology. Element 2: Learn. In the process of application and promotion of educational technology, the society participates in the operation process of educational technology promotion in colleges and universities as an actor, organizer and manager, and plays a role as a bridge and link to connect the education hall, universities and the frontline teachers into an organic whole. Become an important organizational factor in the operational mechanism. Education technology in this area has been applied and popularized effectively due to this new model. It has produced remarkable application results and the greater social influence.

D. MAJOR NETWORK TEACHING PLATFORMS AND THEIR FUNCTIONS IN CHINA

As the network teaching is developing and being widely applied, the main network teaching platforms developed and used in China is on a fast-rising pace and has been applied in many colleges and universities in the mainland. For the time being, relatively mature and stable network teaching platforms with a certain utilization rate include 4A, Crtvu-online, THEOL, Skyclass and Whaty Class etc., yet the well-known platforms such as Web CT, Blackboard, Moodle, open ACS(open source) were all first developed abroad. Among the network teaching platforms independently developed in China, THEOL, Skyclass and 4A are the most widely used online class. Most of these applications are in universities undoubtedly.

Nowadays, in Europe, America and other developed countries, an increasing number of universities are applying the Internet for auxiliary teaching. Network teaching platform has become an indispensable means for teachers and students. Majority of foreign universities attach great significance to the vital role of network teaching platform in teaching assistance. According to Educause CDS (Core Data Service) 2006-2007 survey: In the United States and some other foreign universities, about 98% of nearly 1,000 institutions of higher learning participating in the survey have been equipped with teaching platforms, among which 93% support at least one teaching platform, over 67% have a commercial teaching platform, and 8% have an open source teaching platform. This set of data shows that in foreign countries, colleges and universities put great importance to the application and popularization of network teaching platform, which plays a core role in education teaching in colleges and universities.

As technology improves, education teaching concepts updates and market demands increase, functions of network teaching platform has been continuously improved and perfected. There are scholars started from the composition of the network teaching platform and analyzed the functions of complete network teaching platform: the network curriculum development system mainly in charge of the network curriculum content representation, supports basic teaching logic design, facilitates and speeds up the network curriculum development and so on. The network teaching support system mainly responsible for online course publishing, teachers' teaching support, students' learning support and management in teaching process, which is also the core function of the network teaching platform. The network teaching management system mainly manages online courses and academic status, as well as collects teaching data.

In addition, some scholars have discussed network teaching as a tool to support learning from the perspective of constructivism, which can be summarized into five categories: resource integration, cognitive learning, communication & conversation, teaching evaluation, and teaching assistance.

From the above scholars' different description of network teaching platform functions, we can conclude that network

teaching platform grows with the promotion of network education. For colleges and universities, the main function is embodied in school's teaching management, supports for teaching and for students' learning and so on. These three functions complement and restrict each other.

IV. DEMAND ANALYSIS OF NETWORK TEACHING PLATFORM IN SMART CAMPUS UNDER THE BACKGROUND OF 5G

A. DEMAND ANALYSIS OF SYSTEMATIC BUSINESS

The research object of this paper is students, and the research scene is in the classroom. The function to be realized is to analyze various states of students in the classroom and make corresponding actions through the collection and processing of student information. Students' learning level can be improved by reminding them to concentrate on listening to lectures, or pushing reference materials comparable to their knowledge reserve level. The business requirements of smart class-oriented teaching process management system can be analyzed from the following three aspects: basic management business, recommendation & reminder business, maintenance business. A detailed description of the three services is given below:

- **Basic Management Business:** It focused on the client-side. The modules involved mainly include class management module, course management module, attendance management module, score management module, student management module and homework management module.
- **Recommendation & Reminder Business:** After obtaining and processing relevant data, this business is responsible for proposing relevant reminder information or recommending relevant materials or schemes to the research object, namely the students in class. These relevant data include attributes of students, behaviors of students and scene information of students.
- **Maintenance Business:** The system maintenance business refers to software maintenance that is often involved in software development process. Any software system needs to carry out the basic task of maintenance after it is developed and put into operation.

B. SYSTEM USE CASE MODEL

Users of the system is divided into three categories: students, teachers and administrators.

- **Administrators:** System administrators are mainly responsible for the comprehensive management of smart class teaching system, including the management of class information, course information, user information and system information. Class information—Timely input class name and class time into the system. It also provide class information modification and maintenance functions. Course information—Timely input relevant course information into the corresponding class, and specify the class time for different courses. Meanwhile, the system also supports the modification and maintenance of course information. User information—When the user logs in through the system, it can identify different identities of the user, so as to give them different operation permissions and functions according to their identities. In addition, the system offers the user with the recommendation & reminder function as well as modification and maintenance for user's personal information. System information—Maintain the normal maintenance, update and push functions of the system, making it operate safely and efficiently in real time, so as to ensure the normal operation of class teaching.
- **Teachers:** Teacher users are the principal part interacting with student users in class. Teachers can determine the list of unregistered students by setting the latest check-in time, thus the system is able to send messages to the unregistered students. Teachers can give timely and accurate answers to the questions raised by students online, upload the homework to be assigned, download the homework submitted by students, and finally make a correct evaluation of student users based on class performance and homework completion.

Students: Students are the core users of class activities. They can check their course schedule for this semester. They can ask questions online, and the system will recommend corresponding subject teachers to give answers. The system collects students' facial expressions during class through camera equipment. Through the analysis of their facial expressions, the system gives correct reminders to undisciplined ones. If students input the materials of grade A, B, C and D they would like to refer to (different grades represent different levels of students' professional courses, divided by average score), the system will recommend corresponding learning reference materials based on the grades. In the mean time, student users also have some basic functions, such as downloading teachers' PPT at any time on their own account for viewing during the class. Downloading the homework uploaded by teachers after class and submit homework to the server after completion. When receiving the prompting message of class time and location, students can arrive at the classroom in time for normal learning tasks. The system use case model is shown in figure 6.

V. RESEARCH ON EMOTIONAL LAYER OF NETWORK TEACHING PLATFORM IN SMART CAMPUS UNDER THE BACKGROUND OF 5G

A. DATA ACQUISITION AND PROCESSING OF SCENE PERCEPTION LAYER

The function of scene perception layer is to collect and process all kinds of scene information, which includes time, location and facial information. Time information can be obtained by the system time of mobile terminal. Location information can be captured through GPS sensor and RFID technology of the mobile terminal. Facial information is obtained through camera. See table3 for specific scene information collection device.

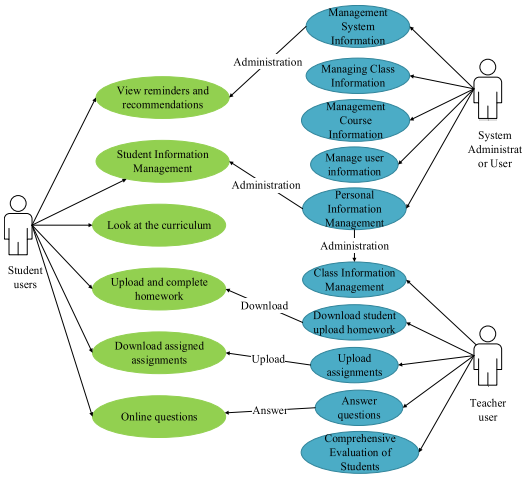

FIGURE 6. System use case diagram.

TABLE 3. Scene information collection devices.

Scene Information	Collection Devices
Time	Time of terminal system
Location	GPS sensor + RFID
Facial	Camera

1) COLLECTION AND PROCESSING OF TIME SCENE INFORMATION

Time scene information can be divided into two big parts, namely, the date and the moment. To further process the date information obtained, it needs to define the period of a day for class and the interval. This paper stipulates that the class time for each lesson is 45 minutes, and the break time has two kinds: 5 minutes and 15 minutes. It takes some calculation to determine whether the current date is a class day or a day off. The class period of a day can be divided into eight periods, that is, eight classes, of which the corresponding table of the class period is shown in table 4.

TABLE 4. Class schedule.

Period	Time Range
The First class	8:50-9:35
Interval	9:35-9:40
The Second class	9:40-10:25
Interval	10:25-10:40
The Third class	10:40-11:25
Interval	11:25-11:30
The Fourth class	11:30-12:15
The Fifth class	13:30-14:15
Interval	14:20-14:25
The Sixth class	14:20-15:05
Interval	15:05-15:20
The Seventh class	15:20-16:05
Interval	16:05-16:10
The Eighth class	16:10-16:55

When the time information is collected, the date is firstly converted into the class day or the rest day, then the acquired time information is converted into the corresponding period in the above table. At this point, the processing of time information is completed.

2) COLLECTION AND PROCESSING OF LOCATION SCENE INFORMATION

Location scene information can be divided into two big parts, namely, acquisition of indoor and outdoor location information. RFID-based indoor positioning technology is used in the acquisition of indoor location information, and the GPS positioning sensor of mobile terminal is used in the acquisition of outdoor location information. Among them, the purpose of collecting indoor location information is not only to determine the specific location of students who signed in in class, but also to prevent some students from signing in to the system outside class. Collecting outdoor location information is to acquire the location of students who did not sign in in class, so as to send reminders to them.

In order to obtain the location information, a simple arrangement in the classroom is necessary. Four readers are assigned at the four corners in the classroom, and sixteen reference tags are evenly distributed in the square space surrounded by the readers. In addition, RFID tags are distributed to all the students in this class in advance, making sure each student has one.

If GPS signal collected by GPS sensor of the mobile terminal is strong, and the RSSI value of the RFID tag on any two readers is particularly weak or there is no RSSI value, then the student user is judged to be outside the teaching building, that is, outside the classroom. If the GPS signal is weak and the RSSI value of RFID tag on any three readers is strong, the student user is judged to be inside the classroom. If both the GPS signal and the RSSI value on each reader are weak, the student is judged to be inside the teaching building but outside the classroom, that is, they are on the teaching building floors [16], [17].

B. POSITIONING MODEL OF VIRE ALGORITHM

VIREVIRE algorithm takes advantage of LANDMARC algorithm principles while introducing the concepts of virtual reference tags and neighborhood maps.

It can be seen from the analysis that the positional accuracy of LANDMARC algorithm is largely dependent on the number of reference tags. However, the addition of too many reference tags will not only increase the early cost, but also the density of tags will greatly interfere with the signal of tags, hence adversely affect positional accuracy. Based on this idea, the concept of virtual reference tags is proposed skillfully: interpolation method is applied to estimate the signal intensity value of virtual reference tags, and these virtual reference tags are put to use as actual reference tags for later calculation and positioning. The positioning model of VIRE positioning algorithm is shown in figure 7.

In the positioning model of VIRE algorithm, the four readers are distributed at four corners in the space, and the reference tags are evenly distributed inside the space. The general idea of VIRE algorithm is to regard every four

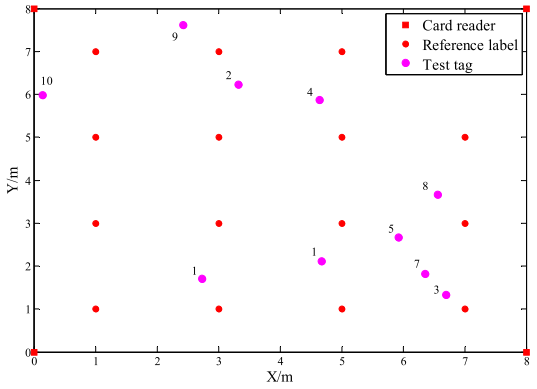

FIGURE 7. VIRE positioning model.

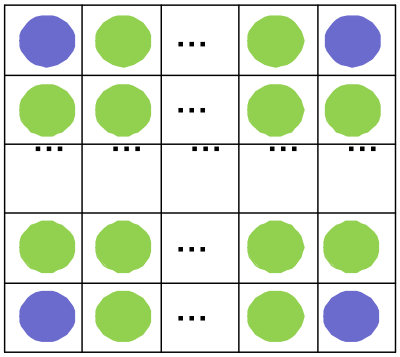

FIGURE 8. Layout of virtual reference tags.

practical reference tags as a unit grid, then further divided them into NxN small grids, which means inserting (2-4) virtual reference tags in each of the four practical reference tags. The layout of the virtual reference tags are shown in figure 8. The distribution of the virtual reference tags is uniform and equally spaced. Since the coordinates of the actual reference tags are known, as a result, the coordinates of the virtual reference tags are easy to calculate, which is equivalent to adding a lot of reference tags in LANDMARC algorithm. We can obtain the RSSI value of the grid virtual reference tags through the RSSI value of the actual reference tags and the linear interpolation.

VIRE algorithm is the same as LANDMARC algorithm: selecting the nearest neighbor reference tags according to the value difference between field intensity value of the pending positioning tags and the reference tags. The difference is that VIRE algorithm introduced the threshold value and marked the position where the value difference of field intensity value between pending positioning tags and reference tags is below the threshold value as 1, whereas marked as 0. Those places marked as 1 therefore constitute a fuzzy map. Since each reader has its own fuzzy map, the intersection of these fuzzy maps can obtain the nearest neighbor reference tags, which are, the reference tags represented by the position of 1 in each fuzzy map.

Besides, VIRE algorithm uses the same weight factor as LANDMARC algorithm when calculating the position coordinates of the pending positioning tags. However, the difference is that the weight factor number of VIRE algorithm is increased from one factors of LANDMARC algorithm to two factors. Calculating the two weight factors according to formula (1) and formula (2):

$$w_{1i} = 1 - \sum_{p=1}^{K} \frac{\left|S_p(T_i) - S_p(R)\right|}{K \times S_p(T_i)} \tag{1}$$

$$w_{2i} = \frac{p_i}{\sum_{i=1}^{n_a} p_i} = \frac{n_{ci}}{\sum_{i=1}^{n_a} n_{ci}} \tag{2}$$

As we can draw from the above, in w_{1i}, $S_p(T_i)$ represents the RSSI value of the i reference tag on the PTH reader. $S_p(R)$ represents the RSSI value of the pending positioning tag on the p reader. The total number of readers is K. w_{2i} is related with the number of virtual reference tags distributed (i.e., density). p_i represents the ratio of adjacent regions connected in the space of the pending positioning region. n_{ci} is the number of contiguous adjacent regions, n_a is the total number of adjacent regions.

Finally, the idea of calculating the position coordinates of the pending positioning tags is the same as that of LANDMARC algorithm. The product sum of the weight factor and the nearest neighbor tag position coordinates is calculated as follows:

$$(x, y) = \sum_{i=1}^{n_a} W_i(x_i, y_i) \tag{3}$$

$$W_i = W_{1i} \times W_{1i} \tag{4}$$

C. POSITIONING MODEL OF IMPROVED VIRE ALGORITHM

Due to the low positioning accuracy of the VIRE algorithm, the following improved VIRE algorithm is used here to obtain the specific coordinate position of the student user in the classroom.

1) SETTING THE THRESHOLD INTERVAL

The original VIRE algorithm employed threshold and fuzzy map to find the intersection, thus obtaining the last nearest neighbor reference tags. Here is the specific idea: marking the position where the difference of field intensity value between pending positioning tags and reference tags is below the threshold value as 1, whereas as 0. In virtue of k readers corresponding to k fuzzy maps, the intersection of these k fuzzy maps can be calculated to obtain the optimal nearest neighbor reference tags. In this process, the selection of threshold value is comparatively important. If the threshold value is too low, and the number of positions marked as 1 from the intersection of k fuzzy maps is too small, some effective nearest neighbor reference tags will be lost being the result. If the threshold value is too high, and there are too large a quantity of the number of positions marked as 1, redundant position information cannot be effectively removed, leading to an inaccurate final positioning result. To prevent the above situation from happening, a concept of threshold interval is proposed [18]–[20].

First, set the initial threshold interval $[a, b]$ as the larger interval. Next, during the running time, checking the number of positions(num) marked as 1 from the intersection of fuzzy maps. Then formula(5) is used to dynamically transform the threshold interval, making sure the value of num be controlled among the interval {4, 5, 6}. Afterwards, the integers in the threshold interval is taken respectively as the threshold value of the improved algorithm to calculate the position coordinates of pending positioning tags. Finally, the mean value of pending positioning tags under these thresholds is calculated as the final position coordinates.

Set the interval A and B belonging to the following set respectively, and evaluate from left to right from the set A and B belong to.

$$[a_1, b_1] = \begin{cases} [a, b] + A, \text{num} \leq 3 \\ [a, b] + B, \text{num} \geq 7 \end{cases} \quad (A \in \{[-1, 0], [0, 1], [-1, 1]\}, \; B \in \{[1, 0], [0, -1], [1, -1]\}) \quad (5)$$

Among the above formula, $[a_1, b_1]$ is the new threshold interval after the threshold interval transformation. After the application of threshold interval, the threshold does not have to perform the procedure of "++" every time in the process of algorithm operation, but can perform "++" or "−" at the upper and lower limits of the threshold interval respectively, which allows threshold transformation more flexible and convenient.

2) MODIFICATION OF WEIGHT FACTOR

It can be concluded from formula (1), w_{1i} decreases as the number of $\sum_{p=1}^{K} \frac{|S_p(T_i)-S_p(R)|}{K \times S_p(T_i)}$ increases. Besides, the error is relatively big in the event of using the first weight factor obtained by formula (1) to calculate the position of the final pending positioning tag, whereas variance formula (6) is the right match: the smaller the variance is, the smaller the fluctuation range of data will be, thus making the positioning error smaller. Therefore, a new calculation method of weight factor is proposed based on this idea, and the calculation formula is shown in formula (7).

$$\sigma^2 = \frac{\sum (x-\mu)^2}{N} = \frac{w_{1i}^{'2}}{K \times S_p(T_i)} \quad (6)$$

$$w_{1i}'' = \frac{1}{w_{1i}^{'} \times w_{1i}^{'}} \quad (7)$$

As the above, $w_{1i}^{'} = \sum_{p=1}^{K} \frac{|S_p(T_i)-S_p(R)|}{K \times S_p(T_i)}$, $w_{1i}^{'2} = \sum_{p=1}^{K} \frac{|S_p(T_i)-S_p(R)|^2}{(K \times S_p(T_i))^2}$. It can be conclude accordingly $\frac{1}{\sigma^2} = \frac{K \times S_p(T_i)}{w_{1i}^{'2}} = w_{1i}'' \times (K \times S_p(T_i))$ that using w_{1i}'' to replace the first original weight factor W1i can relatively reduce the error of pending positioning tags.

The formula of w_{2i} remains as formula (2). Therefore, the calculation method for the weight factor of the nearest neighbor reference tags at this time is formula (7).

$$w_i = w_{1i}'' \times w_{2i} = \frac{1}{w_{1i}^{'} \times w_{1i}^{'}} \times w_{2i} = \frac{w_{2i}}{\sum_{p=1}^{K} \frac{|S_p(T_i)-S_p(R)|}{K \times S_p(T_i)} \times \sum_{p=1}^{K} \frac{|S_p(T_i)-S_p(R)|}{K \times S_p(T_i)}} \quad (8)$$

According to the improved VIRE algorithm from the above, it can be determined that each pending positioning tag is the specific position coordinate of the student user in class. When the student user in this coordinate position needs to ask online questions or in a state of doze off, the system will send necessary reminder messages to him.

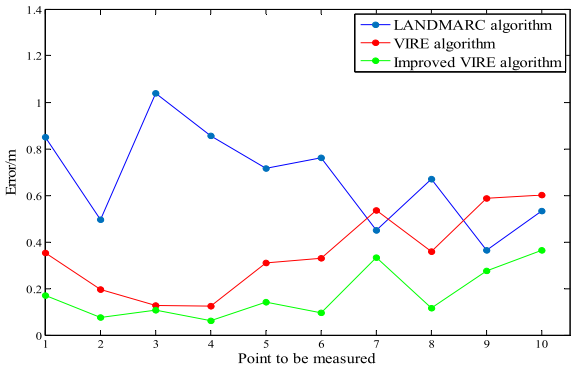

FIGURE 9. Positioning errors of different algorithms.

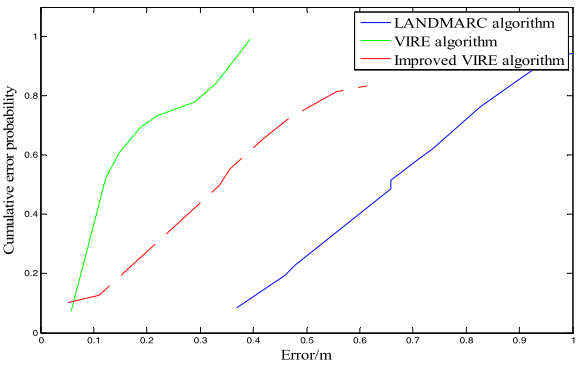

FIGURE 10. CDF error curves fitted by different algorithms.

D. RESULTS ANALYSIS

When obtaining the location scene information, outdoor information could be obtained through the built-in GPS sensor of android system. The built-in class location manager in android system could locate the mobile phone. For indoor location scene information, RFID is used to determine the specific location of students. The specific method is the improved VIRE algorithm. Figure 9 and figure 10 are the comparison between VIRE algorithm and the positioning error of VIRE algorithm and LANDMARC algorithm.

Through the comparison result analysis of figures 8 and 9, we can draw the conclusion that the improved VIRE algorithm has the minimum error and the best effect.

It can be seen from Fig. 8 that the average positioning error of the tag to be located estimated by the improved algorithm is the smallest. Among all 10 to-be-positioned tags, the LANDMARC algorithm has an average positioning error of 0.6732m. The average error of the VIRE algorithm is 0.3517m. The average positioning error based on the improved VIRE algorithm is 0.1738m, which is 0.5058% and 0.7418% lower than the former two. Through the analysis of Figure 9, the improved VIRE algorithm and VIRE algorithm, LANDMARC algorithm positioning error can be compared to obtain the improved VIRE algorithm with the least error and the best effect.

Compared with the traditional VIRE algorithm, the improved VIRE algorithm has more advantages in accuracy, but it takes more time to determine the threshold. Therefore, the VIRE algorithm is suitable for positioning problems with high accuracy and low running time. Therefore, it is more suitable to locate students' specific positions in schools or employees' specific positions.

VI. APPLICATION PROSPECT AND TECHNICAL REALIZATION OF 5G ON NETWORK TEACHING PLATFORM

5G network not only has a higher transmission rate, but also presents the characteristics of low latency, high reliability and low power consumption in transmission, and low power consumption could better supports the application of Smart Campus. 5G network realizes seamless connection among people and could further strengthen the high-speed connection between humans and things as well as between things. Future applications will be developed in a mufti-platform environment. The ultra-high speed of data transmission and senseless delay based on 5G network will bring new experience to students [21], [22].

- **Virtual navigation.** Students can access the location database of the learning areas such as library and classroom in real time.
- **Mobile Distance Teaching.** Students can obtain the teacher's study instructions through the network teaching platform in the self-study room.
- **Students Learning Status Monitoring & Smart Class.** In 5G era, through Internet of Things system and seamless coverage of various teaching areas, teachers can monitor the students' status in class in real-time to get the latest best learning effect. Through observing the state of students, the teaching plan should be adjusted to achieve the best teaching effect.
- **Emergency Communication.** Bad weather conditions and special circumstances will bring down the communication system, yet 5G network will enable the paralyzed communication system to resume work quickly in a short time.

VII. CONCLUSION

This paper introduces the overall framework of Smart Campus based on 5G network in detail. Firstly, this paper analyzes the model of network teaching and the application of network teaching platform in colleges and universities, and finds that the number of network teaching platforms used by colleges and universities increases exponentially. Secondly, this paper conducts business demand analysis, performance demand analysis and function summary design of network teaching platform under the background of 5G. Next, it describes in detail the acquisition and processing of time scene information, location scene information and user scene information in the scene perception layer of Smart Campus network teaching platform under the background of 5G, and uses the improved VIRE algorithm to obtain the positioning effect of small error. At last, this paper illustrates the application prospect and technical realization of 5G network in network teaching platform, which provides a good reference for the construction of network platform of Smart Campus.

REFERENCES

[1] H. Malik, H. Pervaiz, M. M. Alam, Y. Le Moullec, A. Kuusik, and M. A. Imran, "Radio resource management scheme in NB-IoT systems," *IEEE Access*, vol. 6, pp. 15051–15064, 2018.

[2] A. Aissioui, A. Ksentini, A. M. Gueroui, and T. Taleb, "On enabling 5G automotive systems using follow me edge-cloud concept," *IEEE Trans. Veh. Technol.*, vol. 67, no. 6, pp. 5302–5316, Jun. 2018.

[3] S. I. Popoola, A. A. Atayero, J. A. Badejo, T. M. John, J. A. Odukoya, and D. O. Omole, "Learning analytics for smart campus: Data on academic performances of engineering undergraduates in a Nigerian Private University," *Data Brief*, vol. 17, pp. 76–94, Apr. 2018.

[4] G. Bull, J. M. Spector, K. Persichitte, and E. Meiers, "Reflections on preparing educators to evaluate the efficacy of educational technology: An interview with Joseph South," *Contemp. Issues Technol. Teacher Educ.*, vol. 17, no. 1, pp. 11–16, 2017.

[5] Z. Xia, X. Ma, Z. Shen, X. Sun, N. N. Xiong, and B. Jeon, "Secure image LBP feature extraction in cloud-based smart campus," *IEEE Access*, vol. 6, pp. 30392–30401, 2018.

[6] K. Wang, J. Pang, L. Li, S. Zhou, Y. Li, and T. Zhang, "Synthesis of hydrophobic carbon nanotubes/reduced graphene oxide composite films by flash light irradiation," *Frontiers Chem. Sci. Eng.*, vol. 12, no. 3, pp. 376–382, 2018.

[7] L. Kang, H. L. Du, H. Zhang, and W. L. Ma, "Systematic research on the application of steel slag resources under the background of big data," *Complexity*, vol. 2018, Oct. 2018, Art. no. 6703908, doi: 10.1155/2018/6703908.

[8] N.-S. Vo, T. Q. Duong, H. D. Tuan, and A. Kortun, "Optimal video streaming in dense 5G networks with D2D communications," *IEEE Access*, vol. 6, pp. 209–223, 2018.

[9] Y. Lan, C. Xiuli, L. Miao, L. Tianyuan, and M. Qingxin, "Design and implementation of Web-based network teaching platform," in *Proc. 1st Int. Workshop Educ. Technol. Comput. Sci.*, vol. 2, Mar. 2009, pp. 956–958.

[10] C. Zhang and F. Wang, "Notice of retraction student-centered college classroom teaching mode based on network teaching platform," in *Proc. IEEE Int. Conf. Adv. Manage. Sci.*, Jul. 2010, pp. 36–39.

[11] J. Song, Q. Fengm, X. Wang, H. Fu, W. Jiang, and B. Chen, "Spatial association and effect evaluation of CO_2 emission in the Chengdu-Chongqing urban agglomeration: quantitative evidence from social network analysis," *Sustainability*, vol. 11, no. 1, p. 1, 2019.

[12] J. Wen, Y. Xu, Z. Li, Z. Ma, and Y. Xu, "Inter-class sparsity based discriminative least square regression," *Neural Netw.*, vol. 102, pp. 36–47, Jun. 2018.

[13] J. Wen *et al.*, "Robust sparse linear discriminant analysis," *IEEE Trans. Circuits Syst. Video Technol.*, to be published, doi: 10.1109/TCSVT.2018.2799214.

[14] L. Niu, J. L. Xu, W. L. Yang, C. H. Kang, J. Q. Ma, and J. Q. Su; "Synergistic effect between nano-Sb2O3 and brominated epoxy resin on the flame retardancy of poly(butylene terephthalate)," *Sci. Adv. Mater.*, 2019, doi: 10.1166/sam.2018.3434.

[15] Y. Aimin, S. Li, H. Lin, and D. Jin, "Edge extraction of mineralogical phase based on fractal theory," *Chaos, Solitions Fractals*, vol. 117, pp. 215–221, Dec. 2018.
[16] Z. Zeng, L. Huang, L. Dang, L. Sai, Q. Chang, and W. Shi, "RSSI evaluation model for quantitative power-oriented sensing using an omni-directional antenna sensor," *IEEE Sensors Lett.*, vol. 2, no. 1, Mar. 2018, Art. no. 5500104, doi: 10.1109/LSENS.2017.2779497.
[17] F. Liu, Y. Liu, D. Jin, X. Jia, and T. Wang, "Research on workshop-based positioning technology based on Internet of Things in big data background," *Complexity*, vol. 2018, Sep. 2018, Art. no. 7875460.
[18] F. Nan, Y. Suo, X. Jia, Y. Wu, and S. Shan, "Real-time monitoring of smart campus and construction of Weibo public opinion platform," *IEEE Access*, vol. 6, pp. 76502–76515, 2018.
[19] P. Li, Z. Han, X. Jia, Z. Mei, X. Han, and Z. Wang, "Analysis and comparison on thermodynamic and economic performances of an organic Rankine cycle with constant and one-dimensional dynamic turbine efficiency," *Energy Convers. Manage.*, vol. 180, pp. 665–679, Jan. 2019.
[20] Y. Zhao, Y. Liu, and L. M. Ni, "VIRE: Active RFID-based localization using virtual reference elimination," in *Proc. Int. Conf. Parallel Process.*, Sep. 2007, p. 56.
[21] A. Osseiran *et al.*, "Scenarios for 5G mobile and wireless communications: The vision of the METIS project," *IEEE Commun. Mag.*, vol. 52, no. 5, pp. 26–35, May 2014.
[22] M. Chen, Y. Qian, Y. Hao, Y. Li, and J. Song, "Data-driven computing and caching in 5G networks: Architecture and delay analysis," *IEEE Wireless Commun.*, vol. 25, no. 1, pp. 70–75, Feb. 2018.

XIN XU received the B.S. and M.S. degrees from the North China Coal Medical College, in 2003 and 2006, respectively. He is currently pursuing the Ph.D. degree in technology economics and management with the Hebei University of Technology. His main research interests include human resource management, education big data, and so on.

DAN LI received the B.S. and M.S. degrees from the North China Coal Medical College, in 2003 and 2006, respectively. She is currently an Associate Professor with the North China University of Science and Technology. Her main research interest includes teaching management.

MENGYAO SUN received the B.S. degree from the Institute of Disaster Prevention, in 2013, and the M.S. degree from Nankai University, in 2015. His main research interests include the theories of higher education, education big data, and so on.

SHICHAO YANG received the B.S. and M.S. degrees from the North China University of Science and Technology, in 2011 and 2018, respectively. His main research interests include data mining, machine learning, and so on.

SHUJIANG YU received the B.S. and M.S. degrees from the Hebei University of Technology, in 1994 and 1997, respectively, and the Ph.D. degree from the Dalian University of Technology, in 2004. He is currently a Professor with the Hebei University of Technology. His main research interests include human resource management, technological innovation, and so on.

GUNASEKARAN MANOGARAN received the B.E. degree from Anna University and the M.Tech. and Ph.D. degrees from the Vellore Institute of Technology, India. He was a Research Assistant for a project on spatial data mining funded by the Indian Council of Medical Research, Government of India. He is currently a Big Data Scientist with the University of California at Davis, Davis, USA. He is a Co-Investigator for the project Agent Based Modeling of HIV epidemic in State of Telangana, India, funded by Pitt Public Health, Pittsburgh University, USA. He is an author/co-author of papers in conferences, book chapters, and journals. His current research interests include data mining, big data analytics, and soft computing. He received an award for a Young Investigator from India and Southeast Asia by the Bill and Melinda Gates Foundation, USA. He is a member of the International Society for Infectious Diseases and Machine Intelligence Research Labs. He is on the reviewer board of several international journals and has been a member of the program committee for several international/national conferences and workshops. He currently serves on the Technical Program Committee for the 2018 IEEE International Conference on Consumer Electronics, Las Vegas, USA. He is a Guest Editor of various international journals, including IEEE, Springer, Elsevier, Inderscience, IGI, Taylor & Francis, and Emerald publishing.

GEORGE MASTORAKIS graduated from the Department of Electrical and Electronic Engineering, University of Manchester Institute of Science and Technology, U.K., in 2000, and received the M.Sc. degree in telecommunications from the Department of Electrical and Electronic Engineering, University College London, U.K., in 2001, and the Ph.D. Diploma degree in the field of interactive digital television from the Department of Information and Communication Systems Engineering, University of the Aegean, Greece, in 2008. His research interests include mobile computing, wireless systems, interactive marketing, new technologies and marketing, multimedia applications and services, big data, cognitive radio networks, vehicular networks, radio resource management, mobile cloud computing, interactive broadcasting, network management, the Internet of Things, and energy efficient networks.

CONSTANDINOS X. MAVROMOUSTAKIS received a five-year Dipl.Eng. (B.Sc./B.Eng./M.Eng.) degree in electronic and computer engineering from the Technical University of Crete, Greece, the M.Sc. degree in telecommunications from the University College of London, U.K., and the Ph.D. degree from the Department of Informatics, Aristotle University of Thessaloniki, Greece. He is currently a Professor with the Department of Computer Science, University of Nicosia, Cyprus. He also leads the Mobile Systems Lab, Department of Computer Science, University of Nicosia, dealing with the design and implementation of hybrid wireless testbed environments, high-performance cloud and mobile cloud computing systems, modeling and simulation of mobile computing environments, and protocol development and deployment for large-scale heterogeneous networks and new green mobility-based protocols. He has participated in many EU funded projects and regional ones.