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A Location-based Service Framework for Distributed Interactive Multimedia System

Shan Liu[1*], Jianping Chai[1]

[1] School of Information Engineering, Communication University of China, 100024, Beijing, China
liushan@cuc.edu.cn

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Abstract. This paper proposed a new system framework to distribute interactive multimedia system on location-based service. Especially, the paper presented a new solution to the three-dimensional indoor positioning technology based on location fingerprint method. In addition, a new three-dimensional positioning algorithm of NNSS-AP-AVG together with the clustering analysis is proposed to improve the accuracy of the positioning algorithm. By using the NNSS-AP-AVG algorithm, the paper set up a personalized, distributed and interactive multimedia system, which merging the technology of location -based service together. The results of the designed method demonstrated that the new algorithm based on the location fingerprint is significant, which improves the positioning accuracy and optimizes the positioning performance. Finally, the paper evaluated the designed distribute interactive multimedia system and the results demonstrated that the system can give a better performance based on designed location-based service.

Keywords: content distribution, location fingerprint, location-based service, multimedia system

1 Introduction

With the development of wireless network and mobile technology, people tent to use location based service to get access on location information. Location information service has been brought into many fields such as big data, cloud computing, Internet of things, O2O and other new technologies and new applications [1-3].

Our goal is to set up a personalized, distributed and interactive multimedia system, which merging the technology of location -based service together. The information and communication technology together with the location-based services enable us to acquire the personalized information and resources more conveniently and will greatly change the people's daily life style.

The location-based service on a distributed interactive multimedia system is also a kind of positioning system in the field of positioning and navigation. The satellite navigation positioning system and cellular positioning system have been widely used in outdoor environment, but they are not suitable for indoor positioning service, which requires more accurate results than outdoor positioning service. Therefore, our work aims to improve the accuracy of WLAN indoor positioning while the positioning accuracy is more difficult to be guaranteed because of the satellite signal and cellular radio signals which are subject to serious signal attenuation and multipath effects, etc. [4].

Moreover, our work will focus on the research of three-dimensional positioning technology. Because the research of positioning technology in location-based services usually focus on two-dimensional space, but in indoor environments, such as the building of office or shopping mall, the people will also need to know the information of the height. There is still very difficult to carry on the three-dimensional space positioning research using location fingerprint technology, where the three-dimensional space of the offline fingerprint collection is more difficult than two-dimensional space and the accuracy of three-

* Corresponding Author

dimensional space is still need to be improved.

1.1 Related Work

The location-based service of WLAN indoor positioning technology includes Received Signal Strength (RSS), Angle of Arrival (AOA) and Time of Arrival (TOA). The special hardware equipment is required in AOA and TOA positioning technology, which is used for precise measurement and synchronization of angle and time. Compared with AOA and TOA, the RSS does not require additional special equipment and has the following advantages [5-7]:

(1) Fully based on the existing network infrastructure and mobile terminals, no additional equipment is required;

(2) High positioning accuracy within several meters;

(3) The positioning delay is very small, and does not need to search the satellite at the first time.

The RSS still can be divided into two kinds of positioning technologies: location fingerprint method and communication model method [8-11]. These two methods are different in the way that the RSS value of the wireless signal combined with the position information. Because the accuracy of the communication model method is lower and the adaptability to the environment is poorer, the location fingerprint method in the indoor positioning technology is generally preferred. The positioning technology based on location fingerprint can provide less delay of indoor positioning and higher precision.

However, the location fingerprint technology is not mature, and there is no large-scale commercial use in the market. The most important reason is that the location fingerprint technology is required to collect the location fingerprint information, and the work is time-consuming compare with the benefit [12-16]. Furthermore, the two-dimensional spatial positioning cannot meet the needs of location services in many cases and the height of the object and the personnel information is becoming more important. For example, in the event of a fire alarm and other disasters, we need to determine the height, which will impact the rescue effect.

1.2 Contributions

This paper proposed a solution to distribute interactive multimedia system on location-based service and share multimedia resources effectively. Particularly, the research work proposed in this paper is significant for the following reasons:

(1) The research focus on building a wireless roaming network platform in mobile applications, together with the characteristics of reliability, security, scalability. Especially, the object-oriented design patterns are used for the framework analysis.

(2) To improve the accuracy of the location-based service, a new type of three-dimensional positioning algorithm is proposed, which has better performance in indoor positioning technology based on the location fingerprint method.

(3) The influencing factors of the location fingerprint method is studied, which are useful to improve the positioning accuracy and can be the references in arranging the location fingerprint system.

(4) A set of system function modules and terminal server application modules is designed to achieve the goal of multimedia content distribution and sharing information in the wireless roaming network.

(5) The results is significant and demonstrate that the designed system can provide a channel for external communication and internal resource sharing effectively.

3 Location-based Service

The principle of location-based service in location fingerprint method is that the characteristics of the RSS signal received in different physical locations are unique and distinguishable. According to this feature, we can construct a database, which is used to map the physical location to the received RSS signal characteristics. When we know the characteristics of the received RSS signal, we can also get the physical location of the RSS signal.

Indoor positioning based on location fingerprint consists of two stages: offline collection stage and online positioning stage. The main purpose of the offline collection stage is to build the location

fingerprint database and the main purpose of online positioning stage is to estimate the location of the target in the test environment.

The database of fingerprint locations will be set up in the offline acquisition phase, which relating the position information and the RSS vectors. The RSS vector consists of signal intensity received by all APs, which we call it the location fingerprint. In the offline acquisition phase, the user first select a number of reference points in the environment to be tested, and then recorded the entire wireless signal intensities of reference points received by APs. When all the positions of the fingerprints stored in the database, the construction of the location fingerprint database is completed.

The location will be estimated in the online positioning stage, where the user estimated the position using the signal intensity received from each APs. The location fingerprint algorithm is calculated to estimate the position to be measured. The position can be measured both in the three-dimensional space and two-dimensional space. In this paper, the position of the location fingerprint means the space coordinates. The diagram of fingerprint positioning workflow is shown in Fig. 1.

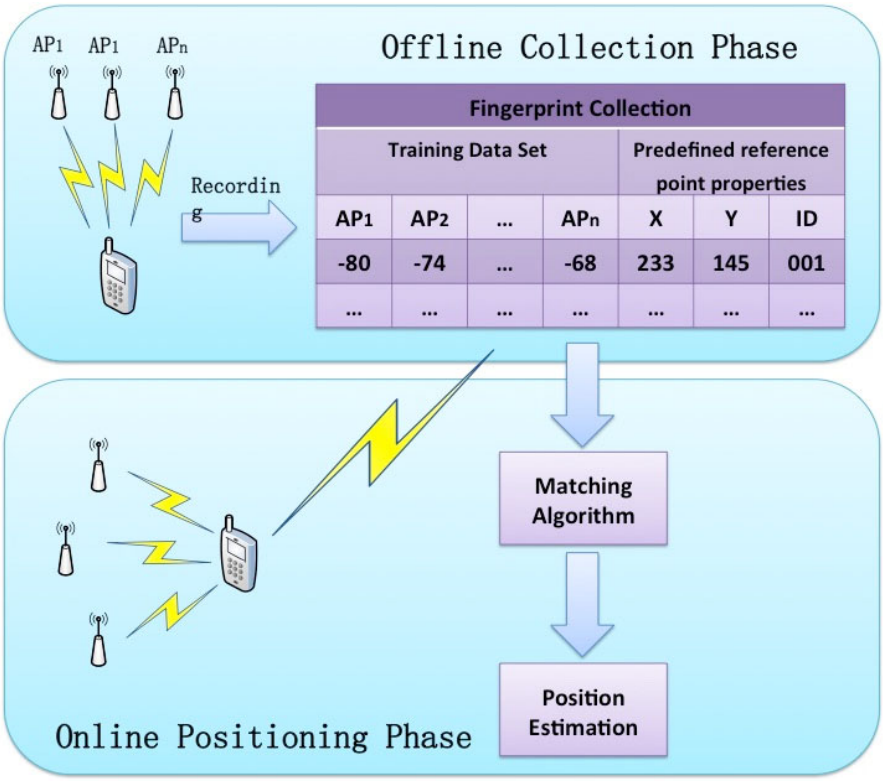

Fig. 1. The diagram of fingerprint positioning workflow

2.1 NNSS-AP-AVG Algorithm

The Nearest Neighbor(s) in Signal Space (NNSS) is the most classical deterministic positioning algorithm, which is proposed by RADAR system.

Our designed location fingerprint positioning system is based on the NNSS algorithm, which will be calculated by the following Euclidean distance equation:

$$Euclidean\ distance = \sqrt{\sum_{i=1}^{n}(F^i - S^i)^2} \quad \textbf{(1)}$$

where the parameter F is location fingerprint data measured in the online position stage and parameter S is the location fingerprint data settled from the location fingerprint database in the offline acquisition phase.

Our work presents a newly designed algorithm named NNSS Adjustable Parameter Average (NNSS-AP-AVG). The NNSS-AP-AVG is calculated as the mean of the first kn minimum of the Euclidean distance, which determined from the location fingerprint data measured in the online position stage and

location fingerprint data settled from the location fingerprint database in the offline acquisition phase.

The algorithm of NNSS-AP-AVG can be implemented as the following steps:

(1) Calculate and order the Euclidean distance of the location fingerprint data to be measured and the location fingerprint data in the database;

(2) Select Q location fingerprint data that less than M times the minimum Euclidean distance;

(3) Compared Q with kn of the initial input, and select the smaller one as P;

(4) Calculated the weighted average of the P location fingerprint data with smaller Euclidean distance, where the weighted average parameters are the normalized Euclidean distance.

There are two main improvements of NNSS-AP-AVG compared with NNSS-AVG:

(1) The fixed kn is modified to a small number between kn and Q, which is called P, and the Q is the number of location fingerprints where the Euclidean distance is less than M times the minimum Euclidean distance.

(2) The estimate average is modified as a weighted average.

2.2 Clustering Analysis

In order to reduce the computation complexity, we introduce a clustering method in the location fingerprint method. Clustering analysis is a multivariate statistical method used in pattern recognition, machine learning, data mining, image processing, etc. Clustering analysis can be divided in hierarchical clustering and non-hierarchical clustering. For hierarchical clustering, the key is to define the class distance. For non-hierarchical clustering, which is referred to a kind of clustering methods, the common feature is to give an immature initial classification, and revise it repeatedly according to some certain rules, until the classification become reasonable. Compared with hierarchical clustering, the non-hierarchical clustering method has better classification accuracy, and occupies less system resources. In this paper, we choose the classical K-means method in non-hierarchical clustering method. The clustering algorithm flow chart is shown as follows:

(1) Set km which is the number of clusters;

(2) Random category the fingerprint data to be measured and the location fingerprint data in the database into km classes;

(3) Calculate the center of gravity as a cluster center;

(4) Calculate the distance between each location fingerprint data and the center of each cluster, and place the location fingerprint data into a class that is represented by the nearest cluster center. Recalculate the center of gravity as a new cluster center;

(5) Repeat step (4) until the resulting classification is no longer changed.

2.3 NNSS-AP-AVG Positioning Algorithm

In order to realize the three-dimensional positioning system based on location fingerprint, we choose a three-dimensional space of 12 meters long, 1.6 meters wide and 2 meters high as an experiment environment, as shown in Fig. 2. To collect the positioning information of location fingerprint conveniently, a wireless roaming network platform in mobile applications is setup with an automatic offline collection system, which including a collection server and mobile collection applications.

We choose the reference points in every 0.8 meters, which high-lightened in the color blue. And the height of the reference points was selected as 0.4 meters, 1.2 meters, 2 meters, respectively. We set up the position to be measured at each reference point of 1.2 meters high, and a total of 28 points to be measured with the red color.

We use NNSS-AP-AVG to implement the MATLAB algorithm. By adjusting the parameters of kn and Q, the three-dimensional positioning accuracy can be achieved by NNSS-AP-AVG algorithm. In detail, we calculate the Euclidean distance between the position of 28 points to be measured and the position of the 135 reference points. Then we get the estimated position according to the NNSS-AP-AVG algorithm, and get the three-dimensional coordinates. The Euclidean distance are calculated between the coordinates of 28 points to be measured and their real coordinates, then the estimation errors are calculated and the CDF and ARMSE are calculated.

First, do the simulation with different kn values when M value is fixed. When M value is fixed at 3.75, and the kn is take as 15, 30, 45, 90, 135, respectively, the results are shown in Fig. 3. When kn equals to 45, as shown in the figure, the CDF reaches the highest value, which means the highest positioning

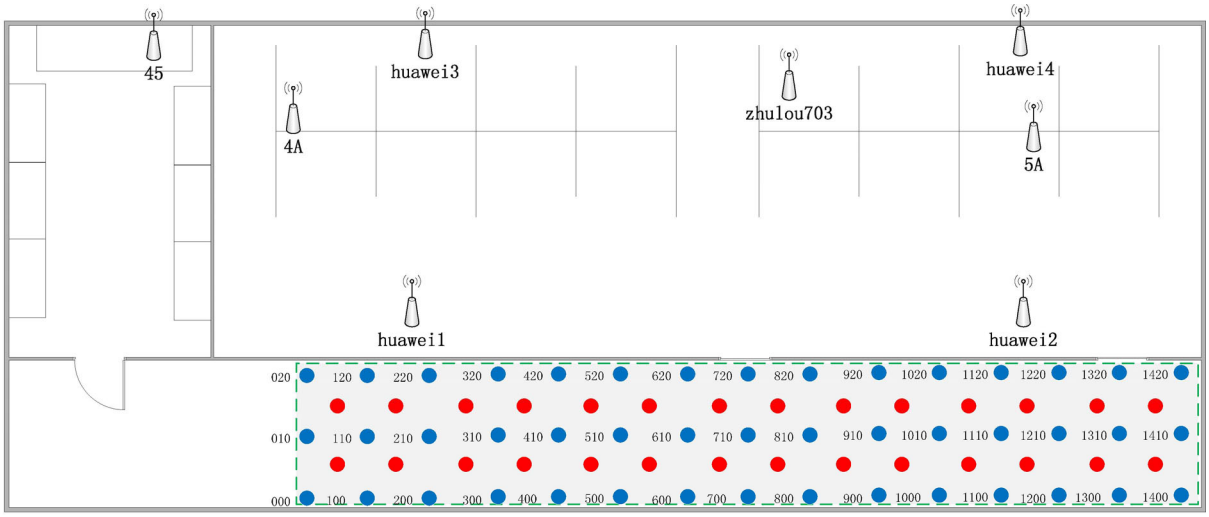

Fig. 2. The layout of reference points in the three-dimensional testing environment

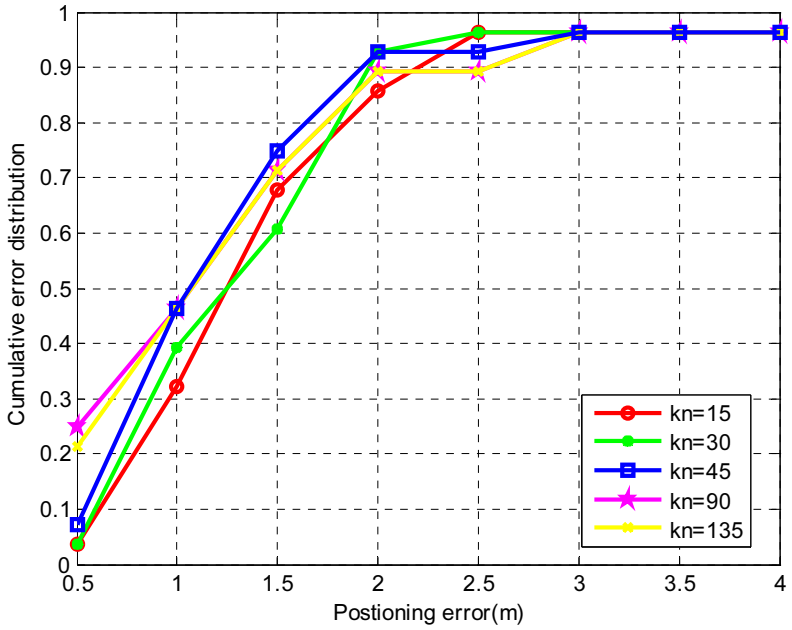

Fig. 3. The results of NNSS-AP-AVG algorithm with different kn

accuracy. When kn equals to 90 or 135, the CDF is higher within a certain range of 0.5 meter. This is because when kn takes a larger value, according to the NNSS-AP-AVG algorithm, M value will take the main role, and will let all the position with similar conditions to involved in the estimation, which may result in a high accuracy in a certain range. But in a larger range of estimation, we need to determine the threshold of kn by simulation. In this paper, kn equals to 45 in the three-dimensional experimental environment.

Then we determine the threshold of kn equals to 45, and do the simulation with different M to test if the positioning accuracy changes. The M values are taken as 1, 1.5, 2.25, 3, 3.75, 4.5, respectively, and the results are shown in Fig. 4. When M equals to 3.75, the CDF reaches the highest value, which means the highest accuracy can be reached at of CDF equals to 96.43% within 3 meters. In the case of M equals to 1, the NNSS-AP-AVG algorithm becomes the NNSS algorithm, and the positioning accuracy is significantly lower than the NNSS-AP-AVG algorithm. When M is less than 3.75, the CDF is increased when M value is increasing. This indicates that more positions involve in the estimation can improve the position accuracy when M value is less than 3.75. Therefore, in this paper, M value is taken as 3.75 in the three-dimensional space experiment environment.

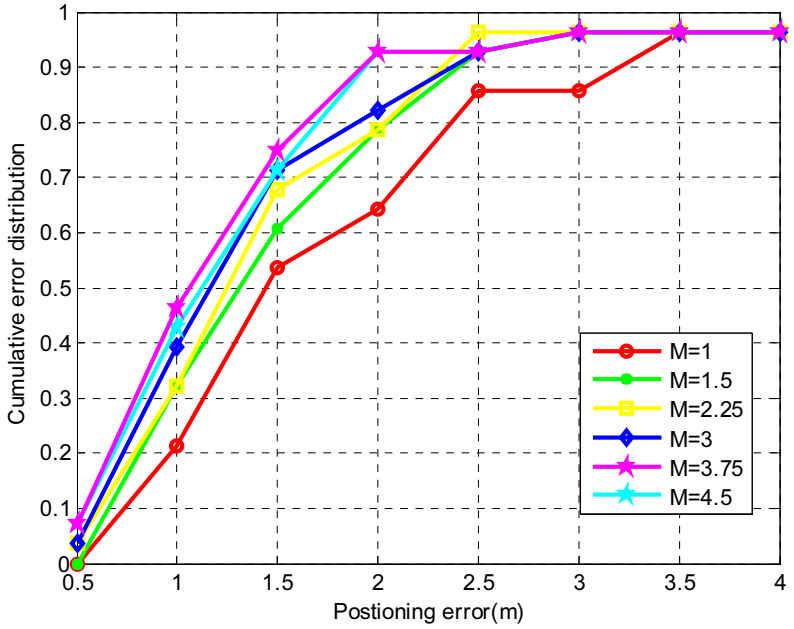

Fig. 4. The results of NNSS-AP-AVG algorithm with different M

In the research of NNSS-AP-AVG algorithm, we also do the simulation with clustering analysis. We still use the K-means algorithm to replace the location fingerprint database of 135 location fingerprint data with cluster. We take kn equals to 45 and M equals to 3.75, respectively, the km is taken from 1 to 6, and the simulation results are shown in Fig. 5. When km equals to 1 with no clustering, the CDF reaches the highest, which means the positioning accuracy is the highest. When km does not equal to 1, the highest CDF can be obtained when km equals to 3, which means the highest positioning accuracy with clustering.

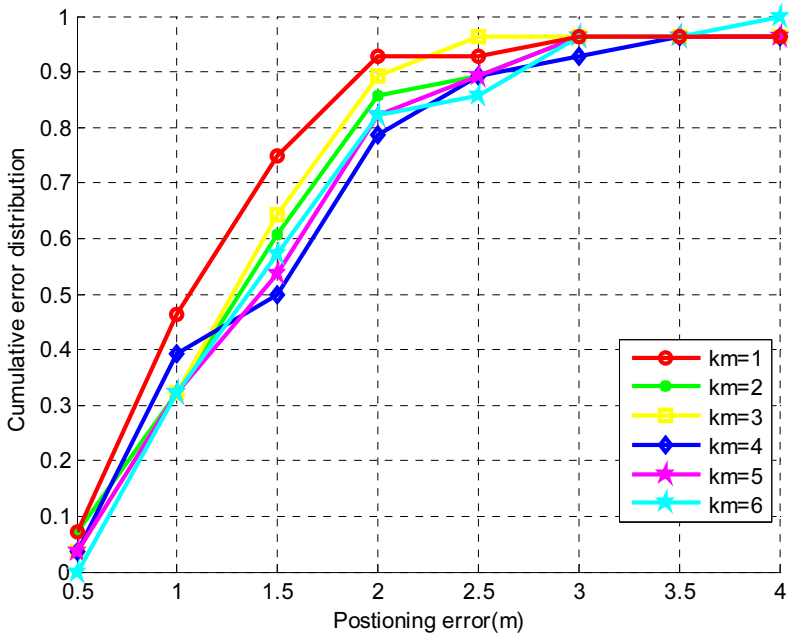

Fig. 5. The results of 3D positioning algorithm with different km

The simulation results show that the clustering analysis can improve the accuracy of the location fingerprint estimation, because the clustering analysis can reduce the calculation time of the Euclidean distance by replace the location fingerprint database with a cluster. Therefore, in the 3D experimental environment, we use NNSS-AP-AVG algorithm with clustering analysis. Its positioning accuracy can

reach when CDF is 96.43% within 3 meters range.

3 System Modules Design

By using the NNSS-AP-ABG algorithm, we can set up a personalized, distributed and interactive multimedia system, which merging the technology of location -based service together. The design stage of the distribute interactive multimedia system on location-based service can be described as the following steps.

3.1 Central Server System Design

Terminal access module. The terminal access module acts as the data transmission channel, which provides information service for terminal users. It provides services to terminal users and records the operation of the user as well.

The terminal access function provides an access entrance for terminal users, which made the system service, based on the system access request, a series of corresponding terminal user.

The data access record function records the process of the data access while the user access the system data. It can record the information such as user login and logout, as well as the access information of multimedia content, which can be used for future data processing and analysis.

Background Management Module. The background management module is the control center of the whole system which managing the information from all the devices in the system. It consists of seven functions modules including login authentication, device link management, division management, multimedia content management, terminal user management, user content monitoring and user profile.

The login authentication function provides a system login entrance for the administrator, where the user login is judged and verified. When the user login is successful, the system will open different function modules according to the user types.

The device link function is designed for maintenance administrator, which mainly support the operation check of wireless device, such as add or delete information. It also enables the administrator to monitoring the running state of the device.

The division management function also belongs to the device link maintenance operations, which mainly focus on the hotspot definition and region division of different system application scenarios. It also enables the addition and deletion of the information to make sure the multimedia content always updated.

The multimedia content management function is designed for content administration, which mainly focuses on importing the multimedia content to the multimedia content library. It also allows the administrator to add or delete the multimedia content information, and bound different multimedia contents with different regions and hotspots, depending on different scenarios of the applications.

The terminal user management function is used to manage the user information and only the valid user information can be used to log on to the system in the terminal application.

The user content monitoring function is responsible for system monitoring and management, especially monitor the user login and logout, as well as the record to access the multimedia content.

The user profile function is designed for the administrators to maintain the user account information.

3.2 Wireless Local Area Network Design

In our system, the hand-held device of the terminal user will access the wireless network and connect to the system server. The dividing area will sometimes exceed the coverage of the single wireless device, so we need to expand the coverage of the wireless network by wireless extension. The common method is to increase the wireless access point in a certain area to expand wireless coverage, but there still will be a big disadvantage. When a user using a hand-held device moves among different access points, he/she needs to find the network and reconnect or even reset every time. There are two ways to solve this problem: wireless network roaming and wireless network bridging.

When there are multiple access points in a particular network, and their micro units have a range of overlap with each other, the wireless user can move among the wireless coverage area where the wireless network card can automatically find the access point with the maximum signal strength and choose to

send and receive data via this access point. By this way, the wireless user will cut off the previous access point and maintain the network connections with the later access point without being interrupted. It appears to be that the user is among an uninterrupted network environment, which is called wireless roaming.

The wireless bridging seems similar to the wireless roaming on the surface, but there are still some differences between them. Wireless bridge increase the coverage area by wireless signal forwarding, which the signal will amplified from one wireless access point to another and so on. It is the relationship between different levels, where the wireless access point of previous level will send and receive the data, in fact. In this way, the root access point will bear greater pressure data, which may affect the whole data transmission speed. Therefore, we choose to use wireless roaming to design our wireless network, which will have a higher transmission speed for the large amount data of multimedia content.

3.3 Terminal Application Design

The terminal application is designed for the center server to access the multimedia contents with personalized information, which mainly refer to the position information of the terminal and the terminal user types. According to different functions and operation processes, the terminal application can be divided into login authentication module, terminal location map display module, multimedia content classification module.

Login authentication module. In this module, the terminal application provides entrance for terminal user to type the user name and password. There will be a data interaction after the user submitting the user name and password to the server for the first time. The request will send to the central server and an authentication result will be sent back. If a successful certification result is get, the center server will also receive the user type information.

Terminal location map display module. This module will be visit after the user authentication is successful. The module will acquire the information of the wireless access point and transmit them to the central server, where the server will return the location information and the user types in this position after data processing by the central server. The designed NNSS-AP-ABG algorithm will be implemented in this module. As a result, the user will have access to the authorized multimedia content information and an electronic map will be displayed. By this way, the users can have an overall perception of their position and multimedia content.

Multimedia content classification module. According to the different types of multimedia content, this module are divided into a number of similar sub-modules, such as video media display module, audio media display module, photo media display module and other media display module. The users can decide which module will be called by their operations. After entering the module, brief description information of the current module and all the multimedia contents will list. The user can choose to access the content he/she interested, such as listening to the audios, watching videos or browsing photos, etc.

4 Evaluation

All the program and terminal application software in this location-based service in distributed interactive Multimedia System are designed by ourselves. The system server and the server and handheld terminal are used in the test.

The test is focus on testing of the wireless roaming function in the campus wireless network. The specific information of system configuration is shown in Table 1. The Endpoint on the server and the client, as well as Console is installed. We run the Chariot Console on the server, and establish point-to-point test cases. While testing, we increase the number of point-to-point connections and monitoring the connection speed and status. Specifically, we change the network connection number for cases, such as one, ten, thirty and ninety pairs for uplink and downlink, respectively. The results of the network connection speed are showing in Figs. 6 to Fig. 9, respectively. From the test results we can see that the uplink and downlink test rate running stably at 125 Mbps, and the designed network keep the stability while a large amount of user accessing to the multimedia content simultaneously.

Table 1. Description of system configuration

System Item		System Configuration
Server	Hardware	Intel(R) Core(TM) i3-2350M, 6G Memory
	Software	Tomcat6.0.35
Client	Hardware	Mobile Phone
	Software	Android 4.0, Handheld Application
Network	Wireless Network	Two TPLINK-TL-WDR3320(600M) Wireless Routers

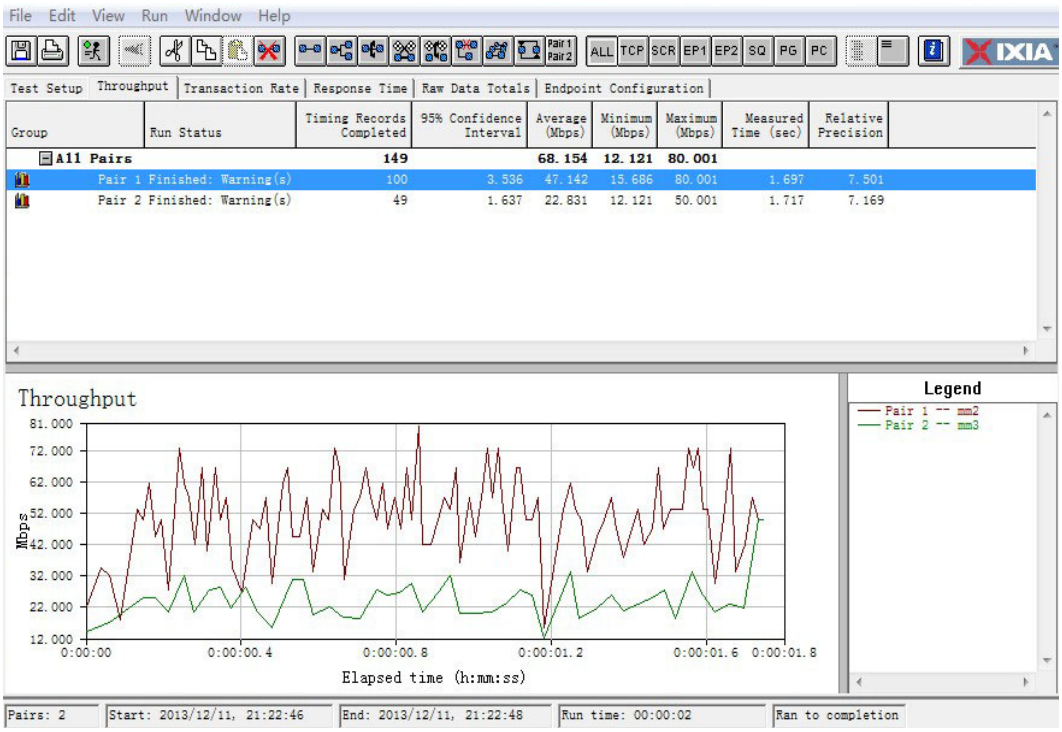

Fig. 6. Network speed for one pair uplink and downlink

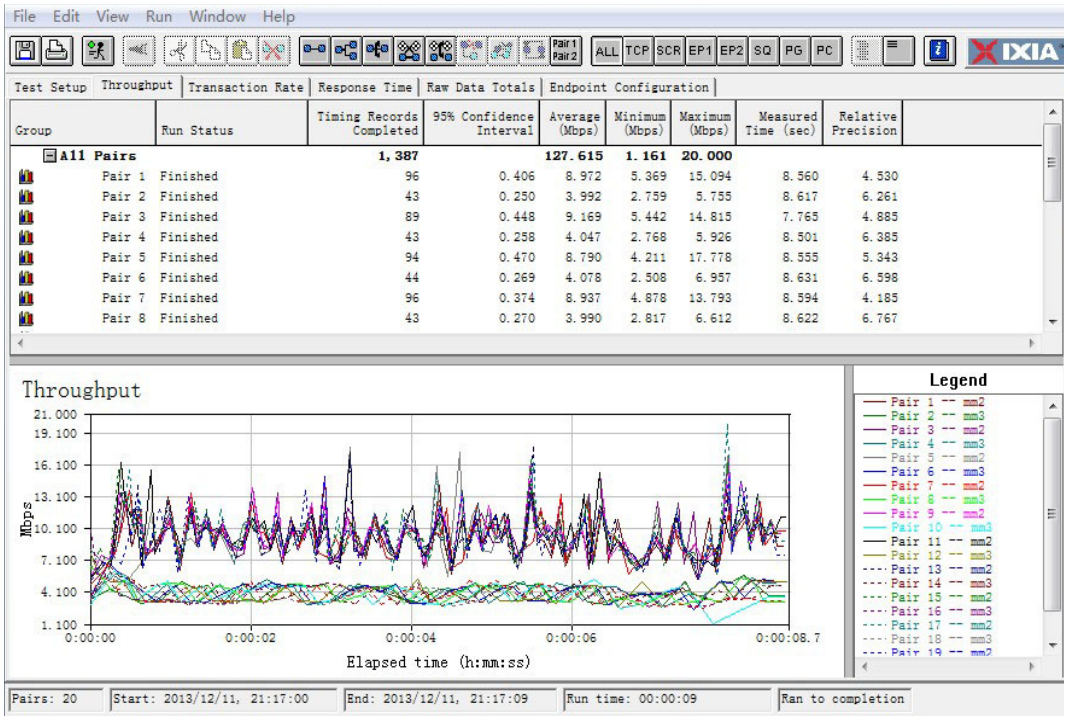

Fig. 7. Network speed for ten pair uplink and downlink

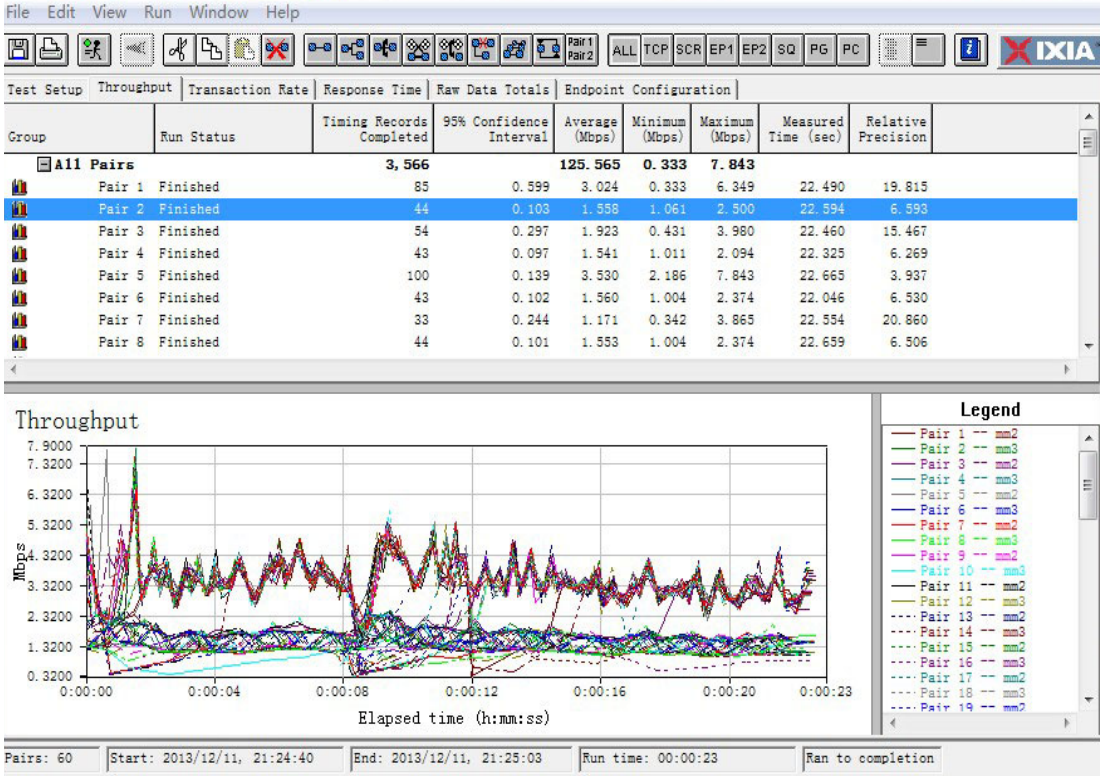

Fig. 8. Network speed for thirty pair uplink and downlink

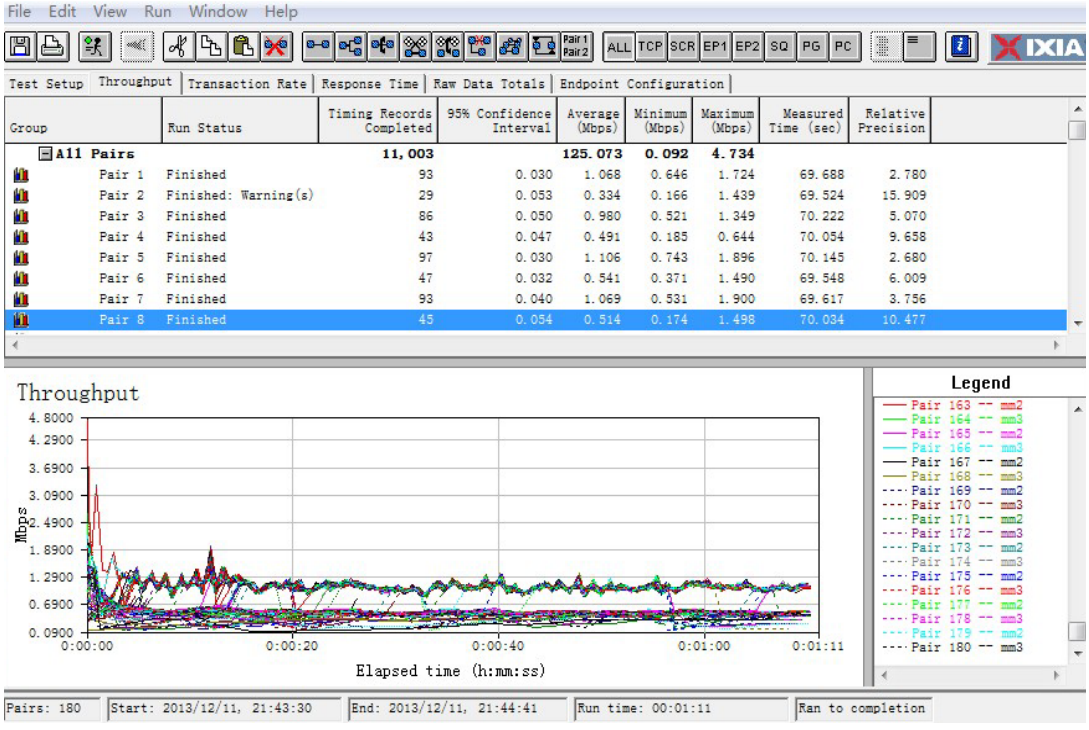

Fig. 9. Network speed for ninety pair uplink and downlink

5 Conclusions

This paper systematically presents a system solution for the location-based service in personalized, distributed and interactive multimedia system. The study of the key technologies and the modules design provide us an overview of the system structure. The analyzes of the system characteristic and demand,

proposes a feasible scheme. In addition, this paper introduces a new three-dimensional indoor positioning algorithm using location fingerprint method. In order to achieve the highest positioning accuracy, we use a novel-positioning algorithm named NNSS-AP-AVG in the location fingerprint method. Moreover, in order to improve the positioning accuracy, we introduce the clustering analysis to reduce the calculation time of the Euclidean distance by replace the location fingerprint database with a cluster. The simulation results demonstrated that the three-dimensional indoor positioning system can achieve higher positioning accuracy when we use NNSS-AP-AVG algorithm with clustering analysis. By evaluating the system performance, the designed system can provide an effective communication channel for the existing environment with a platform for sharing resources. Our future work will expand to a larger network enjoinment and more users.

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