Design and Implementation of Home Video Surveillance Systems Based on IoT Location Service

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ABSTRACT

Due to its simplicity, directness, and rich content, home video surveillance has gradually become the core content of the smart home security system. The rapid development of computer technology, the internet, video image processing, and transmission technology, as well as the emergence of "wireless cities," have continuously expanded the coverage of wireless internet such as 5G and WiFi and greatly changed data processing methods and transmission speeds. Video surveillance has also gradually developed from traditional wired networking to mobile video surveillance of wireless networks. Therefore, this paper will focus on the design of the home video monitoring system based on the IoT location service. The system combines traditional network video surveillance with intelligent mobile terminals, which can meet the needs of users for video surveillance of home conditions at any location and at any time. And it compared the sensitivity, accuracy, capture time interval, and energy consumption of the two by comparing with traditional internet video surveillance.

KEYWORDS

Home Video Surveillance System, Internet of Things, Location Services, Video Surveillance

INTRODUCTION

The continuous progress of human society and rapid economic development have increased living standards, especially in the living environment. Safety, convenience, comfort, energy saving, environmental protection, and intelligence have gradually become synonymous with the new generation of living standards. With the rapid development of modern electronic, automation, and communication technologies, the smart home has emerged as the times require. In recent years, with the continuous in-depth research on smart homes, smart home systems have gradually captured more attention. The smart home is based on the living platform, using advanced technologies, and embedded, to organically combine various subsystems in family life, such as security, lighting, home appliance control, and entertainment systems. The smart home creates a safe, convenient, comfortable,

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energy-saving, environment-friendly, and intelligent home living environment through comprehensive intelligent control and management. *Home monitoring* refers to the use of network technology to connect video, audio, alarm, and other monitoring systems installed in the home and save and send useful information to other data terminals, such as mobile phones, notebooks, the alarm center, BSV LCD splicing screens, and monitors, through the processing of the central control computer.

With the increasing popularity of the Internet, an increasing number of people are communicating across space through the Internet. The *Internet of Things* (IoT) connects objects around people into a network to realize the interaction between objects. Location services obtain the location information of end users through mobile communication networks or global satellite positioning systems and then use it to provide users with various value-added services with the support of communication networks, service and content providers, and application systems. In the advent of the information age, especially the IoT age, many application forms of location-based services have been gradually realized from the original idea and become a development hotspot in the mobile Internet and geographic information industry. The use of location services has increased with the continuous development of mobile network technologies, such as 4G, 5G, and Wi-Fi, and smart terminal operating systems and hardware devices, which are mainly represented by Android and IOS, and the technological development and cost reduction of positioning equipment, such as Beidou and the global positioning system (GPS). In China, the coverage of wireless networks has continuously increased due to the popularity of 5G applications and the concept of a "wireless city." Free Wi-Fi access points in some public places in Beijing, Guangzhou, Hangzhou, and other provinces have been set up, such as public transportation, catering, and entertainment places, increasing the coverage of wireless networks and thus enabling the realization of a mobile video surveillance system. This paper studies the home video surveillance system and explores the efficacy of the video surveillance system based on IoT location services, providing a reference for home video surveillance system research. The innovation of this paper lies in solving the problems of traditional home video monitoring, such as single mode and poor monitoring effect.

RELATED WORK

To achieve intelligent identification, positioning, tracking, supervision, and other functions, any object can be connected to the network using information-sensing hardware and in accordance with a predetermined protocol. The connected objects then exchange information through an information dissemination medium. Experts and academics at home and abroad have addressed the potential uses of IoT location services in numerous industries and conducted pertinent research on their technical and application aspects. Zhou et al. proposed a Wi-Fi-enabled, non-intrusive device–user association technique called WinDUA, through a new unsupervised association learning algorithm to verify user identity and achieve mobile localization. This technique uses a Wi-Fi-based indoor positioning system to obtain the historical location data of each mobile device. Through hierarchical clustering and the location similarity matching between its location data and the user's personal space, the specific location of the user is associated (Zhou et al., 2019).

Pandey et al. combined multi-level linear regression and Gaussian mixture model (GMM) methods to address the device orientation and heterogeneity of heterogeneous smart devices. They used the method to detect malicious data on the IoT and estimate the location of sensor failure. Furthermore, they tested the performance of the method using Wi-Fi signals in an indoor environment. The results show that the GMM method can accurately estimate the location of heterogeneous smart devices (Pandey et al., 2019).

Çiftler et al. (2017) studied the accuracy of received-signal-strength-based wireless localization using passive UHF radio frequency identification equipment (RFID) systems, considering monostatic and bistatic configurations and 3D antenna radiation patterns. It is designed to provide a wide range of location-based services for low-power IoT applications. They found that the positioning accuracy is reduced at blind spots outside the RFID reader's antenna radiation pattern. At this time, optimizing the antenna elevation angle can improve the positioning coverage, and using a bistatic configuration can significantly improve the positioning accuracy.

Wang et al. realized source localization based on the time difference of arrival (TDOA) of non-line-of-sight (NLOS) signal propagation. Existing robust least squares (RLS) methods suffer from two drawbacks: (1) an extremely large NLOS error upper bound and (2) inexact triangle inequality problems. To overcome the shortcomings of the existing RLS methods, they proposed two new RLS formulations. First, the NLOS error in the jointly estimated source position and reference path is calculated to reduce its upper bound. Second, a balance parameter is introduced to avoid using triangle inequality (Wang et al., 2019).

Want et al. studied accurate indoor positioning for the IoT. They combined the IoT and precise positioning technologies to enable a range of novel context-aware services to automate tasks and support daily work practices. The research includes IEEE 802.11-REVMC and Wi-Fi round-trip time, the significance of improving positioning accuracy, location data, and privacy, and the future development of positioning technology (Want et al., 2018).

Given the large data generation offered by the IoT settings, location services based on received signal strength indication (RSSI) for obtaining location fingerprints have become increasingly prevalent. However, such services will not be typical features in upcoming smart facilities because creating radio maps through offline RSSI fingerprinting is time-consuming and tedious. Sikeridis proposed a location-aware infrastructure that includes deep sensing layers, edge computing, and centralized cloud joint support to solve such issues. This configuration provides the structures inside the facility with a sensing system that facilitates fingerprint location services (Sikeridis et al., 2018).

According to Varma and Anand, indoor positioning is one of the essential smart infrastructures for creating smart buildings and cities. They suggested a random-based machine learning algorithm. As an IoT service for smart buildings, this algorithm focuses on improving the positioning accuracy of indoor positioning. Their experimental results show a 14% improvement in the test prediction success rate in terms of overall bias (Varma & Anand, 2021).

IOT AND LOCATION SERVICES

Internet of Things

The loss or cost function maps the value of a random event or its related random variables to non-negative real numbers to represent its risk or loss. With the rapid development of contemporary productivity, the cross-integration of multi-disciplinary technologies, and the promotion of growing application demands in recent years, the IoT has steadily gained attention and research focus from around the world. It connects any object to the Internet in accordance with the agreed-upon protocol and exchanges and communicates information, realizing intelligent identification, tracking, monitoring, positioning, and management (Kanakaraja, 2021). This is implemented using infrared sensing equipment, RFID, laser scanners, global positioning systems, and other information identification and sensing equipment. The IoT's functionality shows that it can fulfill any service requirements at any moment and environment for any object, person, enterprise, or business, using any communication method (Zhu et al., 2021).

The IoT architecture can be broken down into three levels from a macro perspective: the first level is the perception layer, which is used to perceive the outside world; the second level is the network layer, which is used to transmit and process data; and the third level is the application layer, which is used to apply the data (Mohamed et al., 2019).

The *perception layer* gathers object data and implements object recognition. This layer is made up of various sensing and object identification modules. EPC tags, readers, RFID readers, sensors, sensor networks, and short-range wireless communication devices are some of the linked modules (Chou et al., 2019). These modules perform intelligent object identification, gather various data, and transfer object information to the network layer over a network. An intermediary link in the operation of the IoT, the *network layer* is the information transmission link between the perception and application layers (Cvitić et al., 2021). This layer's primary role is the transmission and processing of data information. That is, it processes the data information collected by the perception layer and communicates it to the *application layer*. This layer guarantees the IoT's efficient overall operation and accurate data transmission (Long et al., 2021). To support its information transmission function, a network with a high carrying capacity is needed. As illustrated in Table 1, the networks that can be utilized to transmit sensing data mostly fall into the following three types.

The supporting technology and application service layers are both parts of the application layer. The supporting technology layer, which includes cloud computing, high-performance computing, and mass storage, is in charge of collecting data from the network layer and executing data collection, analysis, and transformation in accordance with user needs (Zhang, 2021). The application service layer provides users with services in all facets of life in accordance with their needs, including smart homes, telemedicine, environmental monitoring, urban management, and green agriculture, this by presenting processed information to users in the form of services.

Location Services

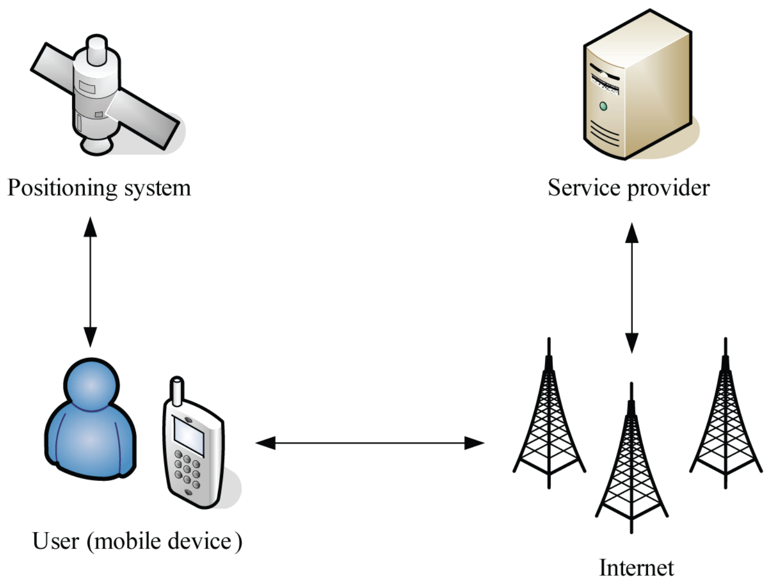
Deep learning involves learning the underlying principles and layers of representation of sample data, and the knowledge acquired through the learning processes is very useful for interpreting data types, including text, images, and sounds. The ultimate objective of deep learning is to provide machines with the capacity to evaluate, understand, and recognize information, such as words, images, and sounds, in the same way that people do (Zhao & Zhou, 2022). Given that a user's specific location can be obtained anytime and anywhere, location-based services play an increasingly important role in people's private and public lives. That is, a location service provides needs based on the user's location. For example, location-based emergency services can search for the nearest hospital for an emergency patient, and location-based entertainment information services can search for a movie theater or hotel within a specified distance from the target location.

The *k*-means algorithm is an unsupervised learning technique that uses an indirect grouping method based on the similarity between samples. This algorithm separates *n* items into *k* clusters, where each cluster has a high degree of similarity, and each cluster's degree of similarity is low. Location service relies on mobile communication networks (such as GSM and CDMA networks) or other positioning methods (such as Wi-Fi and GPS) to obtain the actual location information of mobile terminal users. This service provides users with information services closely related to their own location, including positioning, navigation, query, and identification. With the rapid development of mobile communication networks and electronic information technology and the enhancement of mobile terminal performance, location service has been attracting increasing attention, promoting the application of location services. Location service has extended to various fields closely related to people, such as health, daily life, study, and work. Generally, the basic system framework of location-based services includes four types of entities: users (mobile devices), positioning systems, Internet networks, and service providers, as shown in Figure 1.

Table 1.
Network for transmitting sensing data

Communication Network Type	Specific Classification
PAN network	ZigBee, UWB, Wi-Fi, Bluetooth
LAN network	Ethernet, Wimax, WLA
WAN network	G PRS, CDMA, 3G, 4G, 5G

Figure 1.
Basic system framework based on location service



The user is the owner of a mobile device through which location-based service query requests can be sent. Mobile devices can be smart phones, tablets, and so on and must have two basic functions: Internet access and location positioning. The Internet access function allows the user's mobile device to access the Internet through wireless access points or cellular base stations and send location-based service requests to service providers. The location positioning function enables the user's mobile device to obtain the current location information of the user through the built-in positioning module. In addition, in the mobile user's ad hoc network architecture, the user's mobile device must have an additional wireless network card to realize a P2P network through a specific ad hoc network protocol.

In location-based services, the main function of the positioning system is to provide accurate location information for users when requesting services. Two kinds of positioning methods are commonly used at present: the positioning methods based on the satellite and base station positioning systems. The positioning method based on the satellite positioning system mainly determines the specific position of the user equipment through multi-satellite cooperative calculation. Commonly used satellite positioning systems include GPS, China's Beidou satellite system, Europe's Galileo positioning system, and the assisted GPS combined with base station positioning technology. The positioning method based on the base station positioning system utilizes multiple base stations to determine the specific position of the user equipment through triangular formula calculation.

The Internet is responsible for the network communication between the user equipment and the service providers (Ghahramani et al., 2021). With the development of 5G technology and the improvement of base station communication technology, users have been able to access the Internet freely and enjoy high-quality information exchange services. Depending on the possibility of putative eavesdropping, the information transmitted over the Internet can be encrypted or unencrypted. The main role of service providers is to provide feedback to users regarding query results through database retrieval and data calculation according to various location-based service query requests submitted by users (such as POI search and friend location query; Tortonesi et al., 2018).

Indoor positioning technology is also gaining popularity with the development of IoT location services. The research focus of indoor positioning technology is generally based on parameterized indoor positioning technology. The indoor positioning technology based on parameterization refers extracts required relevant parameters from the indoor environment. Then, the parameters are reasonably estimated, and the positioning technology is applied according to the estimated results. The main technologies involved are the time of arrival (TOA), TDOA, angle of arrival (AOA), RSSI, and hybrid positioning estimation technologies (Chong-Woon, 2017).

TOA Estimation Techniques

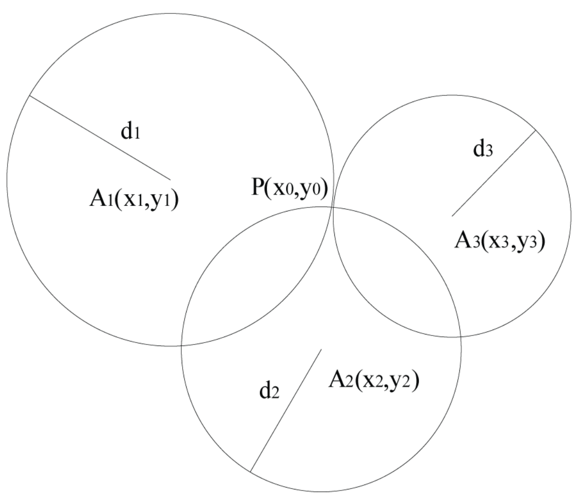
The TOA positioning technology uses the time difference of the lightning electromagnetic pulse arrival at different stations for positioning. According to the hyperbola characteristics, a time difference is obtained between two stations to form a hyperbola, and any point on the hyperbola is a possible lightning return position. In addition, a time difference exists between two stations, which can also form another hyperbola. The intersection of two hyperbolas is a lightning return position. The TOA is a wireless positioning technology based on the time of arrival of signals. Given the propagation speed, the TOA technology converts the arrival time of the signal into the distance measurement and then calculates the distance according to the relevant algorithm after obtaining the distance information.

The positioning principle of the TOA algorithm is shown in Figure 2. Three or more readers are used for signal transmission with the mobile tag. When the mobile tag enters the positioning area, if the signal propagation time between the *i*th reader and the tag to be located is t_i and the transmission speed of the radio frequency is *v*, then the actual distance between the object to be located and the reader is:

$$d_i = v * t_i \quad (1)$$

The distance between the three readers and the tag to be located can be obtained by Equation 1. Then, the positioning solution is applied according to the triangulation method shown in Figure 3. If the coordinates of the label to be positioned are, then the following can be obtained according to the formula of the circle:

Figure 2.
Positioning principle of the TOA algorithm



$$\begin{cases}\left(x_1 - x_0\right)^2 + \left(y_1 - y_0\right)^2 = d_1^2 \\ \left(x_2 - x0\right)^2 + \left(y_2 - y_0\right)^2 = d_2^2 \\ \left(x_3 - x0\right)^2 + \left(y_3 - y0\right)^2 = d_3^2\end{cases} \tag{2}$$

By deforming the nonlinear formula system in Equation 2, the following linear formula system can be obtained:

$$B = AX \tag{3}$$

where:

$$A = \begin{bmatrix} 2\left(x_1 - x_3\right) & 2\left(y_1 - y_3\right) \\ 2\left(x_2 - x_3\right) & 2\left(y_2 - y_3\right) \end{bmatrix} \tag{4}$$

$$B = \begin{bmatrix} x_1^2 - x_3^2 + y_1^2 - y_3^2 + d_3^2 - d_1^2 \\ x_2^2 - x_3^2 + y_2^2 - y_3^2 + d_3^2 - d_2^2 \end{bmatrix} \tag{5}$$

After the transformation, X can be obtained as follows:

$$X = \left[x, y\right]^T \tag{6}$$

Although the position of the moving object with the tag is calculated, the TOA method synchronizes the clocks of the reader and the tag to be located by default. However, keeping the clocks synchronized is difficult and can easily cause errors. Therefore, clock synchronization is a defect of the TOA positioning technology. In addition, serious NLOS and multipath problems exist because the positioning environment is indoors, which will cause errors in the ranging process, affect the final position calculation, and interfere with the final positioning accuracy. Therefore, attention should be given to the positioning scene in the application of this kind of method.

TDOA Estimation Techniques

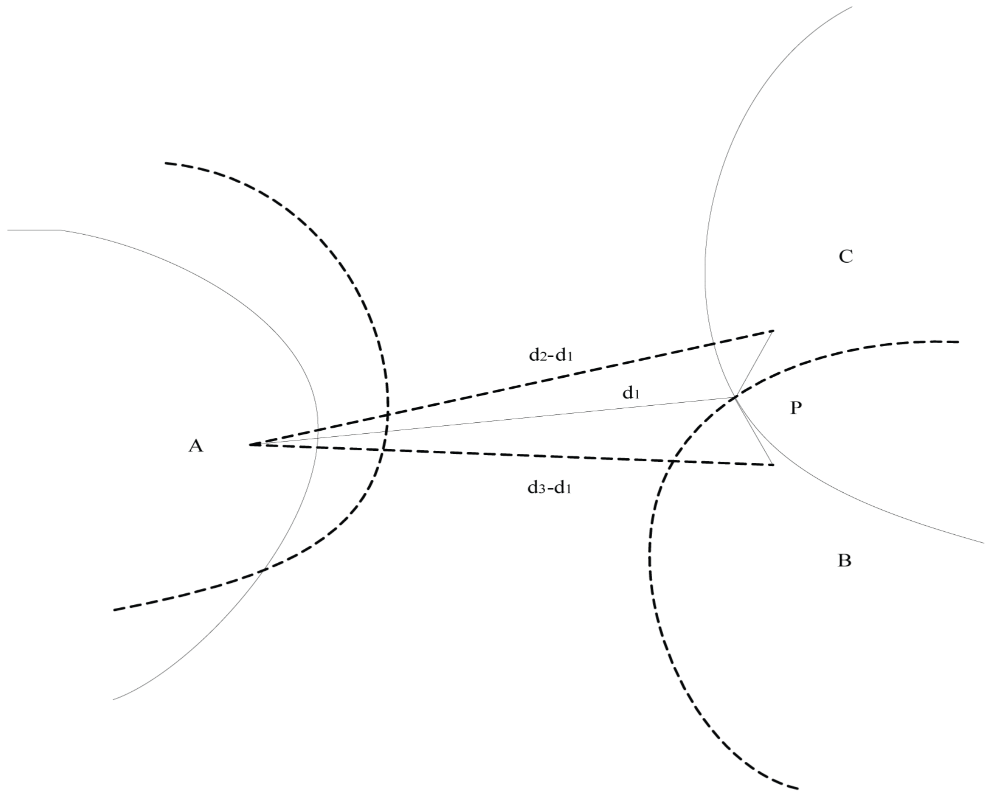
TDOA is a wireless positioning technology based on the time difference of arrival of signals. This technology is an improvement of the TOA technology, so it is very similar to the TOA estimation technology. The TDOA of the signal received by the two antennas is measured and effectively converted into distance according to the distance formula (Pradhan et al., 2021).

The positioning principle of the TDOA algorithm is shown in Figure 3. According to the hyperbola in the conic section, one reader must be placed on the hyperboloid formed by the other two readings each time a TDOA measurement is taken. The distance between the two readers and the one reader is fixed. Therefore, the position coordinates are solved by the hyperboloid positioning method.

By deforming Equation 2, the following formula can be obtained:

$$d_i^2 = \left(x_i - x_0\right)^2 - \left(y_i - t_0\right)^2 \tag{7}$$

Figure 3.
Positioning principle of the TDOA algorithm



Then, the difference between the distances between the tags to be located and readers *i* and *j* can be set as $d_{i,j}$, which is expressed as:

$$d_{i,j} = d_i - d_j = \sqrt{\left(x_i - x_0\right)^2 + \left(y_i - y_0\right)^2} - \sqrt{\left(x_j - x_0\right)^2 + \left(y_j - y_0\right)^2} \tag{8}$$

Thus, the geometric relationship between the tag to be positioned and the three readers can be obtained as:

$$\begin{cases} d_{2,1} = \sqrt{\left(x_2 - x_0\right)^2 + \left(y_2 - y_0\right)^2} - \sqrt{\left(x_1 - x_0\right)^2 + \left(y_1 - y_0\right)^2} \\ d_{3,1} = \sqrt{\left(x_3 - x_0\right)^2 + \left(y_3 - y_0\right)^2} - \sqrt{\left(x_1 - x_0\right)^2 + \left(y_1 - y_0\right)^2} \end{cases} \tag{9}$$

Equations 7–8 indicate that:

$$d_i^2 = \left(d_{i+1} + d_i\right)^2 \tag{10}$$

By substituting Equations 7–8 into Equation 10, we obtain:

$$d_{i,1}^2 + 2d_{i,1}d_1 = x_i^2 + y_i^2 - 2\left(x_i - x_1\right)x_0 - 2\left(y_i - y_1\right)y_0 - x_1^2 - y_1^2 \tag{11}$$

The formula is a system of linear formulas with three unknowns, which can be solved by the least squares method to obtain the coordinate position of the label to be located. The TDOA estimation technique overcomes the clock synchronization problem in the TOA technology, thereby easing the requirement for the high precision of the equipment. TDOA technology is very similar to TOA technology in that it mainly changes the conversion factor of the distance from time-to-time difference, but the signal transmission environment remains unchanged. Therefore, TDOA is also affected by NLOS and multipath interference, which affect positioning accuracy.

AOA Estimation Techniques

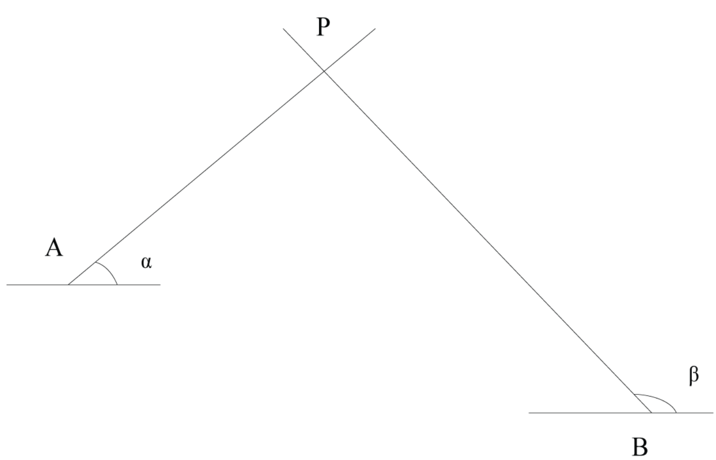
In project management, one of the two representations of the network diagram. AOA is a network diagram method that uses arrows to represent works and nodes to represent the relationship between works. This technology is called double code network AOA. AOA is a wireless positioning technology based on the angle of arrival of signals. The AOA positioning algorithm requires additional hardware equipment array antennas and has high complexity. AOA mainly collects the direction information of the signal through the directivity of the antenna.

The positioning principle of AOA is shown in Figure 4. The RFID tag transmits a signal to the RFID reader or reflects the signal transmitted by the RFID reader so that the reader can use the signal arrival angle or azimuth measured by the array antenna. Then, the position information of the object to be located is calculated by the triangulation method (Kasana et al., 2018).

As shown in Figure 5, the geometric principle is as follows:

$$\left\{\begin{array}{l} \tan\alpha_1 = \dfrac{x_0 - x_1}{y_0 - y_1} \\ \tan\alpha_1 = \dfrac{x_0 - x_2}{y_0 - y_2} \end{array}\right\} \tag{12}$$

Figure 4.
Positioning principle of the AOA algorithm



By solving Equation 12, we can obtain the following:

$$x_0 = \frac{-x_1 \tan\alpha_1 + x_2 \tan\alpha_2}{\tan\alpha_2 - \tan\alpha_1} \quad (13)$$

$$y_0 = \frac{-y_1 \tan\alpha_1 + y_2 \tan\alpha_2 - \left(x_1 - x_2\right)\tan\alpha_1 \tan\alpha_2}{\tan\alpha_2 - \tan\alpha_1} \quad (14)$$

The AOA positioning estimation algorithm does not need to synchronize the clock between the reader antennas and is simple. However, this algorithm has high hardware requirements, including an array antenna, and is easily affected by indoor environmental noise and NLOS. Moreover, the positioning accuracy of the AOA algorithm is lower than that of the TOA algorithm.

RSSI Estimation Technique

RSSI technology is a wireless positioning technology based on the received signal strength. According to the signal attenuation model, it follows the propagation of the signal in the environment. The signal strength is continuously attenuated with the propagation and converted into a measure of distance through the relationship between the attenuation of the signal strength and the logarithmic model of the distance. Then, the positioning solution is carried out by the triangulation method.

The most typical signal strength-distance model is the free-space propagation model, which can be obtained from the Friis formula:

$$\frac{P_r}{P_t} = \frac{A_t A_r}{d_2 \lambda_2} \quad (15)$$

The gain of the antenna is obtained as follows:

$$\begin{Bmatrix} G_r = \dfrac{4\pi A_r}{\lambda^2} \\ G_t = \dfrac{4\pi A_t}{\lambda^2} \end{Bmatrix} \quad (16)$$

The effective radiation power $\left(P_{EIRP}\right)$ of the RFID tag is:

$$P_{EIRP} = P_t G_t \quad (17)$$

where P_t represents the power transmitted by the antenna of the RFID tag, and G_t represents the gain of the transmitting antenna. Therefore, the propagation model of the available signal is shown in Formula (18), and the received power of the RFID reader signal is:

$$P_r = P_{EIRP} G_r \left(\frac{\lambda}{4\pi d}\right)^2 \quad (18)$$

where G_r represents the gain of the receiving antenna, λ represents the wavelength of free space, and *d* represents the distance between the RFID reader and the tag. Therefore, the distance between the reader and the tag can be calculated from the transmit and receive powers.

Given the complex indoor environment and considering the actual environment or the inaccuracy of the free-space model solution, the transmission environment may also be determined according to the environment. Therefore, the log-normal distribution model is consistent with the actual positioning environment. Assuming that the path loss coefficient of different positioning environments is *n*, the model is shown in Equation 19:

$$P_r\left(d\right) = P_t - PL\left(d_0\right) - 10n\lg\left(\frac{d}{d_0}\right) + \varsigma \tag{19}$$

$$PL\left(d\right) = PL\left(d_0\right) = 10n\lg\left(\frac{d}{d_0}\right) + \varsigma \tag{20}$$

where $P_r\left(d\right)$ represents the received power when the distance between the RFID reader and the tag is d, and P_t represents the transmitted power of the signal. $PL\left(d_0\right)$ represents the corresponding *PL* value when the reference distance is d_0, and ς represents a random variable that follows a normal distribution.

DESIGN OF HOME VIDEO SURVEILLANCE SYSTEM

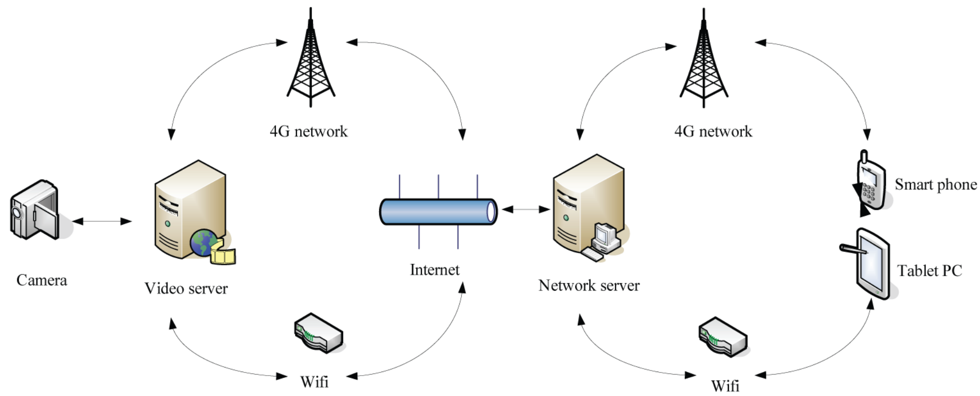
Home video surveillance is an important part of the home security system and is a comprehensive system with a strong preventive ability. A video surveillance system is mainly composed of five major parts: acquisition, recording, transmission, control, and display. According to the different functions of each part of the system, the entire system can be divided into seven layers: the acquisition, processing, transmission, support, control, execution, and presentation layers. The functions of each layer are shown in Table 2.

The hardware and software systems mainly make up a home video surveillance system. The operating system, the camera driver software, the video collector control system, and other software comprise the software system; home wireless cameras, routers, PCs, and other gear comprise the hardware system. The Windows XP operating system is utilized for the video capture control system, and MFC is used to create the programs. Figure 5 depicts the connections between the elements of a home video surveillance system.

Table 2.
Hierarchy division of video surveillance system

Layer	Function
Acquisition layer	Collect image information through camera
Processing layer	Digital process, compress and store video signals
Transport layer	Transmit processed signal through the wireless network
Support layer	Protect and support the equipment in each link
Control layer	Control and manage the whole system
Executive layer	Execute control command
Presentation layer	Display the picture information and alarm information

Figure 5.
Component composition diagram of a household video monitoring system



The camera collects the video pictures of the monitored point and transmits the picture to the video processing server through USB. The video server calls the corresponding hardware device to process the video image, which mainly includes adjusting the capture parameters, the image analysis parameters, and the user-defined settings and analyzing and processing video information. The monitoring terminal is actually the reverse process of the video processing server, which parses the received data packets. Then, through hardware decoding, display playback, storage, and send control instructions when the front-end equipment needs to be controlled.

The software part of the system has designed the overall framework, which consists of three parts: client, server, and bottom applications. The system framework is shown in Figure 6. The client is implemented based on the browser, providing users with front- and back-end interfaces. The server is deployed on the wireless module to process user requests. The underlying application is mainly the hardware driver of the home video surveillance system.

When the user logs in to the operation interface for control, the browser client initiates an HTTP request to the server. After the server receives the request, it parses the request, executes the corresponding Web application program according to the parsed request parameters, drives the hardware to perform corresponding actions, or performs operations, such as adding to, deleting from, modifying, and querying the database. Finally, according to the situation, the execution result of the Web application is returned to the client for presentation. The Web application cannot directly operate the robot hardware; it needs to call the relevant functions of the driver to control the hardware. For this task, the C language is used to write the hardware driver, and the relevant interface of the Web application program to operate the hardware is provided. The greatest advantage of the application is its accessibility. Users only need a browser and no other software to access the web application.

EXPERIMENT VERIFICATION OF HOME VIDEO SURVEILLANCE SYSTEM

A GPS receiver receives the satellite signals of the global positioning system and determines the position of the ground space. The navigation and positioning signal sent by the GPS is an information resource that can be shared by countless users. The vast number of users on land, sea, and space have equipment that can receive, track, transform, and measure GPS signals, that is, GPS signal receivers. The GPS receiver is connected to the computer correctly, and the serial port debugging tool is used for debugging the receiver. After debugging 100 times, the data was analyzed and processed, and the debugging results obtained are shown in Table 3.

Figure 6.
Software system architecture diagram

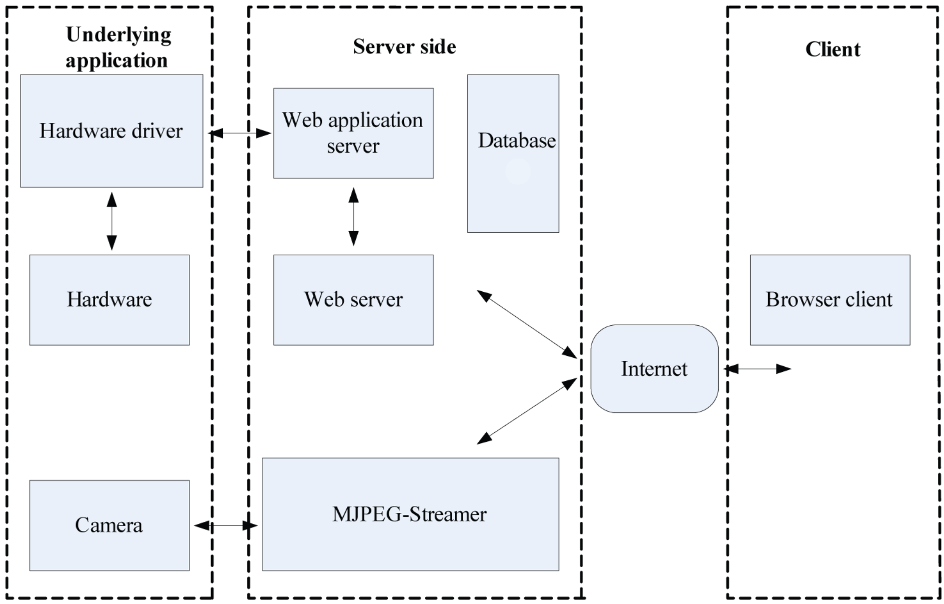


Table 3.
Test results of GPS

Test Item	Function
Update frequency	1 Hz, 5 Hz
Hot start delay	< 4s
Cold start delay	< 40s
Recapture delay	< 0.5s

Given the different network bandwidths of different places, even the bandwidth of the same place in different time periods fluctuates. To make the video surveillance run better, it can show better video quality on the premise of ensuring smoothness. The transmission parameters of the video should be changeable. Based on this consideration, the video surveillance system reserves an interface for changing video parameters. It can choose the appropriate video frame rate (in frames per second, or fps) and resolution according to the network environment to make the video clear and smooth.

Combining the commonly used video resolutions and frame rates of 10 and 20 fps, four experimental groups were obtained, as shown in Table 4, and the network traffic of each combination is detected. The software for monitoring traffic in this article uses DUMeter. DUMeter is the most popular network traffic monitoring software. This software occupies a small memory, has a user-friendly interface, and is easy to use. The network traffic can be displayed digitally and graphically, which is convenient for post-processing and analysis.

This test is performed in a Wi-Fi environment with a laptop. According to the video parameter table in Table 4, four different video parameters are configured, each parameter is tested for 45 s, and the test results are obtained. Figures 7 and 8 are screenshots of the network traffic obtained using DUMeter, where the horizontal axis represents time in seconds, and the vertical axis represents the network speed

Table 4.
Video parameters of traffic monitoring experimental group

Serial Number	Resolution (ppi)	Frame Rate
E1	320×240	10
E2	640×480	10
E3	640×480	15
E4	640×480	30

in kb/s. Figures 7a and 7b are the E1 and E2 real-time network traffic test charts. Figure 7 shows that the average network rate of E1 (with a resolution of 10 and a frame rate of 10) is 49.35 kb/s, the maximum rate is 91.6 kb/s, and the minimum rate is 2.4 kb/s; E2 (resolution, frame rate 10) has an average network rate of 93.01 kb/s, a maximum rate of 171.7 kb/s, and a minimum rate of 4.2 kb/s. The network speed increased by 88.5% after changing the resolution of the video. The analysis shows that the larger the video resolution is, the larger the occupied bandwidth and the network speed are.

Figure 8a and 8b are the E3 and E4 real-time network traffic test charts, respectively. The analysis of Figure 8 shows that the average network rate of E3 (resolution is 15) is 58.86 kb/s, the maximum rate is 109.8 kb/s, and the minimum rate is 2.3 kb/s; E4 (resolution, frame rate 30) has an average network rate of 97.11 kb/s, a maximum rate of 189.2 kb/s, and a minimum rate of 1.7 kb/s. When the frame rate of the video is changed from 20 fps to 40 fps, the network rate increases by 65.0%. The analysis shows that the higher the frame rate is, the greater the occupied bandwidth and the network rate are. Furthermore, the video resolution has a greater impact on the network bandwidth than the frame rate.

The designed video surveillance system based on the IoT is compared with the current video surveillance system based on the Internet, and the sensitivity and accuracy of the two in different monitoring areas and their capture time interval and energy consumption are compared. The obtained results are shown in Figures 9 and 10. Figure 9a and 9b show the sensitivity and accuracy of video surveillance systems based on the Internet and the IoT under different monitoring area sizes, respectively. The analysis of Figure 9 reveals that the Internet-based video surveillance system has the highest sensitivity in the monitoring area of 10, which is 8.24. In the monitoring area of 20, 30, and 40, the sensitivity is 6.74, 5.46, and 4.93, respectively; the sensitivity of the video surveillance system based on the IoT is 8.4 and 8.22 in the monitoring area of 10 and 20, respectively. The sensitivity in

Figure 7.
E1 and E2 network traffic test comparison chart

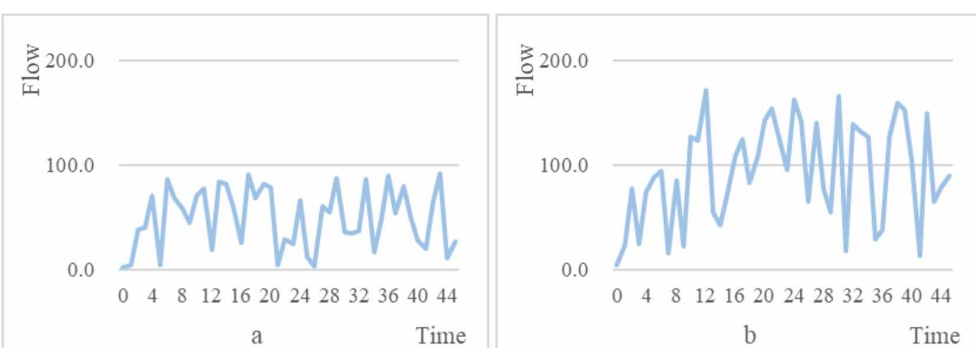
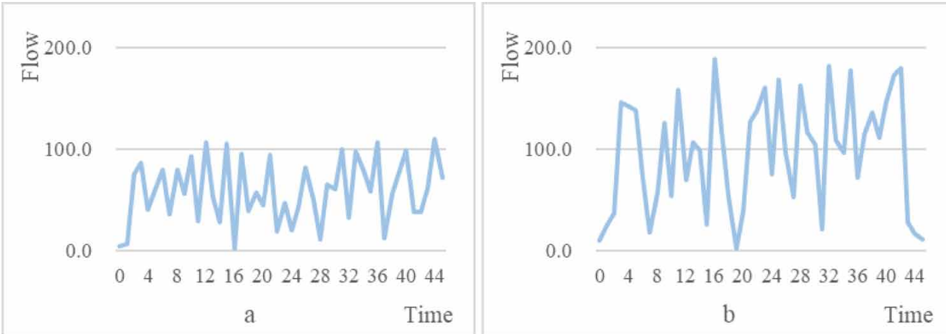


Figure 8.
E3 and E4 network traffic test comparison charts



the monitoring area of 30 and 40 is 6.72 and 6.64, respectively. The accuracy of the Internet-based video surveillance system in the monitoring area of 10 is 8.41, and the accuracy in the monitoring area of 20, 30, and 40 is 7.12, 6.94, and 6.8, respectively; the accuracy of the video surveillance system based on the IoT is 9.2 and 8.84 in the monitoring area of 10 and 20, and the sensitivity in the monitoring area of 30 and 40 is 8.27 and 7.93, respectively. The IoT-based video surveillance system is higher than the Internet-based video surveillance system in terms of sensitivity and accuracy.

Figure 10a and 10b show the capture time interval and energy consumption of the video surveillance system based on the Internet and the IoT under different monitoring area sizes, respectively. The analysis of Figure 10 shows that the Internet-based video surveillance system has the shortest capture time interval in the monitoring area of 10, which is 200 ms. The capture time intervals in the monitoring areas of 20, 30, and 40 are 1,000, 1,500, and 1,800 ms, respectively; the video surveillance system based on the IoT has capturing time intervals of 200 and 600 ms in the monitoring areas of 10 and 20, and 800 and 1,000 ms in the monitoring areas of 30 and 40, respectively. The energy consumption of the Internet-based video surveillance system in the monitoring area of 10 is 400 mA, and the energy consumption in the monitoring area of 20, 30, and 40 is 900, 1200, and 1600 mA, respectively; the video surveillance system based on the IoT consumes 400 and 800 mA in the monitoring area of 10 and 20, and 1,000 and 1,100 mA in the monitoring area of 30 and 40, respectively. The video surveillance system based on the IoT is lower than the video surveillance system based on the Internet in terms of capturing time intervals and energy consumption.

Figure 9.
Capture sensitivity and accuracy test chart

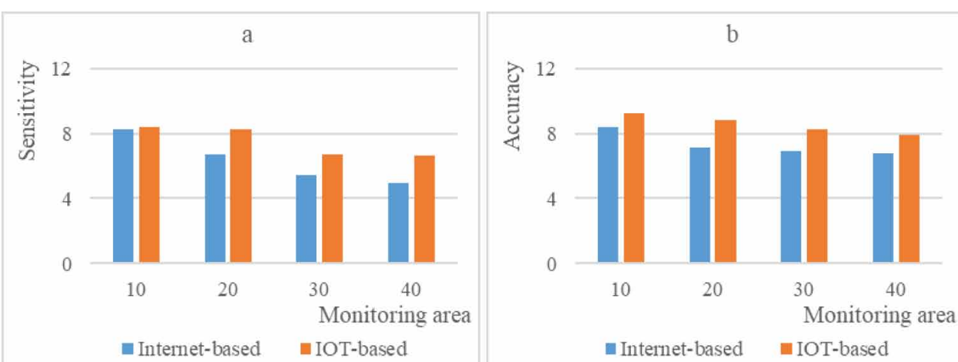
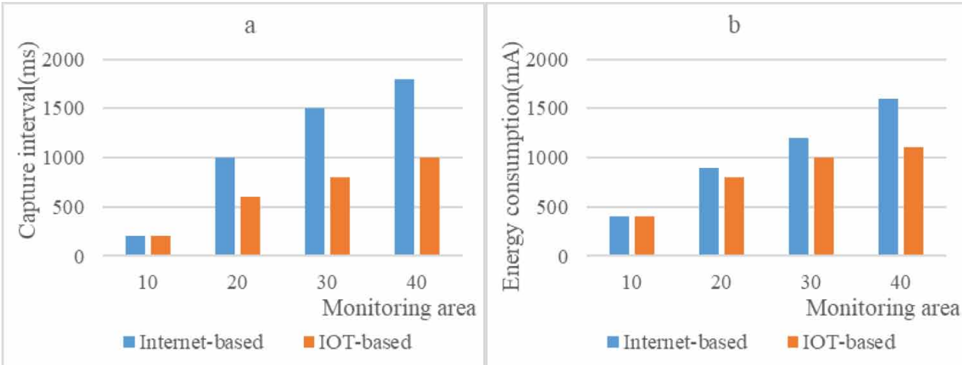


Figure 10.
Capture time interval and energy consumption test chart



CONCLUSION

This paper carried out a great amount of research work on video surveillance based on the location information of the IoT and performed system and hardware integration and verification work in the process of designing and developing the system, realizing most of the functions in the system and achieving the preset goals. The video network occupied bandwidth test demonstrated that the larger the video resolution is, the higher the frame and network rates are. That is, the video resolution has a greater impact on the network rate than the frame rate. In addition, the article focuses on the technologies required for system development, such as the capture interval, the design of capture sensitivity, and the image similarity algorithm, and the preliminary experimental results of using the system for actual monitoring are presented. The experimental results show that the system can accurately capture the dynamic image information in a simple background and can meet the needs of real-time monitoring for home use. However, due to limited time and energy, the current system only collects videos, and the function is relatively simple. Temperature, humidity, and other sensors can also be installed in the system to monitor the temperature, humidity, and other conditions in the home, increasing the comprehensiveness of the system.

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