Cloud-based data management system for automatic real-time data acquisition from large-scale laying-hen farms

Chen Hongqian[1,2], Hongwei Xin[3], Teng Guanghui[1*], Meng Chaoying[4], Du Xiaodong[1], Mao Taotao[1], Wang Cheng[4]

(1. *College of Water Resources and Civil Engineering, China Agricultural University, Beijing 100083, China*;
2. *Network Center, China Agricultural University, Beijing 100083, China*;
3. *Department of Agricultural & Biosystems Engineering, Iowa State University, 1202 NSRIC, Ames, IA 50011-3310, USA*;
4. *College of Information and Electrical Engineering, China Agricultural University, Beijing 100083, China*)

Abstract: Management of poultry farms in China mostly relies on manual labor. Since such a large amount of valuable data for the production process either are saved incomplete or saved only as paper documents, making it very difficult for data retrieve, processing and analysis. An integrated cloud-based data management system (CDMS) was proposed in this study, in which the asynchronous data transmission, distributed file system, and wireless network technology were used for information collection, management and sharing in large-scale egg production. The cloud-based platform can provide information technology infrastructures for different farms. The CDMS can also allocate the computing resources and storage space based on demand. A real-time data acquisition software was developed, which allowed farm management staff to submit reports through website or smartphone, enabled digitization of production data. The use of asynchronous transfer in the system can avoid potential data loss during the transmission between farms and the remote cloud data center. All the valid historical data of poultry farms can be stored to the remote cloud data center, and then eliminates the need for large server clusters on the farms. Users with proper identification can access the online data portal of the system through a browser or an APP from anywhere worldwide.

Keywords: cloud-based data management system (CDMS), egg production, intensified laying-hen farms, asynchronous data transmission, metadata

DOI: 10.3965/j.ijabe.20160904.2488

Citation: Chen H Q, Xin H W, Teng G H, Meng C Y, Du X D, Mao T T, et al. Cloud-based data management system for automatic real-time data acquisition from large-scale laying-hen farms. Int J Agric & Biol Eng, 2016; 9(4): 106－115.

1 Introduction

Poultry industry in China has been growing rapidly over the last 20 years. The total poultry production in China is leading the world with one-third of the global output. In order to improve management and operational efficiency, production scale (farm size) is becoming increasingly large. However, application progress of

Received date: 2016-04-01 **Accepted date:** 2016-06-01

Biographies: Chen Hongqian, PhD candidate, Network Engineer, research interests: environmental control technology and agricultural informatization, Email: chenhongqian@cau.edu.cn; **Hongwei Xin**, Professor, Director of Egg Industry Center, research interests: environmental control of animal housing, computer vision, precision livestock production, Email: hxin@iastate.edu; **Meng Chaoying**, Professor, research interests: computer system, Email: mcy@cau.edu.cn; **Du Xiaodong**, PhD candidate, research interests: environmental control technology, Email: duxiaodong@cau.edu.cn; **Mao Taotao**, Postgraduate, research interests: biosensors and system control, Email: maotaotao@cau.edu.cn; **Wang Cheng**, Postgraduate, research interests: database technology, Email: 814311175@qq.com.

***Corresponding author: Teng Guanghui**, PhD, Professor, research interests: environmental control of animal housing, computer vision, precision livestock production. Postbox 195, College of Water Resources and Civil Engineering, China Agricultural University, No.17 Qinghua East Road, Haidian District, Beijing 100083, China. Tel: +86-10-62737583, Email: futong@cau.edu.cn.

information technology (IT) for the industry is still slow. Poultry production data are mostly collected as paper documents because such large quantities of valuable data fail to be stored digitally. This practice of record-keeping and handling large volumes of data makes it difficult to monitor, examine, and assure performance and quality of today's poultry production.

Many studies have been reported recently that worked on Precision Livestock Farming (PLF) systems and farm management systems. Currently, most of them focused on the management of environmental data or certain production segments[1-3]. There have been few studies worked on integrated systems for the whole poultry farming process[4-6]. Moreover, data of them were only been collected and saved for a short period, on-line analysis of the farming process and quality assurance is difficult[7-9]. For the poultry industry, accumulation of data during production process can effectively reflect the living conditions of the animals[10,11]. Therefore, the information can also be used to trace the source of the products[5,12]. For farmers, accumulation of the field data can help them to understand business conditions of their farms.

However, establishing data management system for large-scale egg production is not an easy task. Most of the real-time data from the poultry farms are in the forms of streaming data, which means the data are generated continuously at a fast rate[13-15]. Data produced from different devices or equipment can vary greatly in types and formats. Certain characteristics are required for the data management system, such as real-time, high performance, distributed, extensible, etc.

With the rapid development of information and communication technology (ICT), such as computer technology, internet of things, distributed technology and information security technology, it is now possible and more affordable to manage big data[16-21]. This research proposed an integrated cloud-based data management system (CDMS) for improved management of large-scale laying-hen farms. There are four major advantages identified for the CDMS implementation: First, the cloud provides a platform for many different farms to share the information technology infrastructure. Moreover, computing resources and storage space can be allocated according to need. Second, the system significantly advance the ability of modern poultry producers in their efficient management of big data, record-keeping, and real-time visualization of the flock performance and housing conditions. In addition, automatic data acquisition module of the CDMS can save manpower, make farm management more efficient, and improve data quality and completeness. Third, the user-friendly management tool of the system contributes to improving animal well-being, production performance, efficiency in the use of natural resources, and ultimately enhance sustainability of the industry. Fourth, the CDMS provides app, which enables the staff to operate the system anywhere on the farm with a mobile phone. The proposed data management system used cloud computing, asynchronous data transmission, distributed file system, and wireless network technology, and a systematic description of the system design and implement was provided.

2 System architecture

The CDMS is service oriented and has a distributed architecture, it can manage data from different chicken farms. In this particular case, there are three chicken farms accessing the CDMS, i.e., Shangzhuang Station, Yanqing DQY chicken farm, and Huangshan DQY chicken farm. Authorized users can access the online data portal of the system through a browser or an APP (Figure 1).

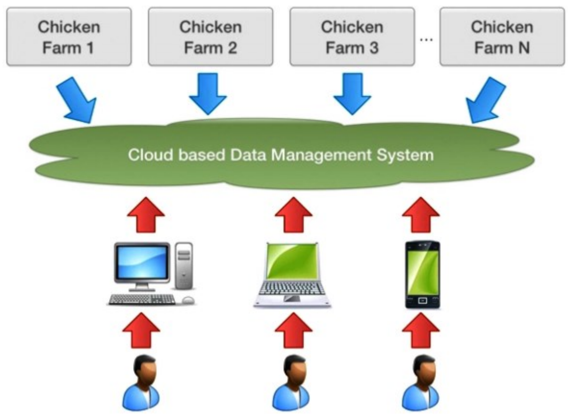

Figure 1 Schematic representation of cloud-based data management system (CDMS)

The CDMS consists of local farm servers and a remote cloud data center. Field data collected from the chicken farms will be transferred to the cloud data center asynchronously according to the following steps (Figure 2).

Step 1. The field data include automatically acquired real-time data and manually filled data. Real-time data are collected by sensor nodes deployed in and out of the henhouse. Manual data are submitted through the web page or smartphone device of the clients. The field data are stored in the database and file system of the local server.

Step 2. A daemon program is deployed on the local server to detect the update of newly stored data and sent the data to a Kafka cluster. The Kafka cluster is deployed for communication between the farms and the remote cloud data center. The Kafka system is distributed, scalable, with high throughput and fault tolerant ability. The system will keep multiple backups to ensure that the data are not lost. Consumers can consume multiple backups at the same time, which significantly improves the system throughput[22].

Step 3. When the data are transferred to the remote cloud data center through the Kafka cluster, a Data-Canal cluster is deployed in the cloud data center to subscribe data from the Kafka cluster, and generates a task. The Data-Canal cluster also processes the tasks.

Step 4. The Data-Canal cluster saves the structured data (the data stored in the local farm server's database) to the database in the cloud data center. The Data-Canal cluster then saves the unstructured data, such as pictures, audios and videos, to the distributed file system. The Data-Canal cluster also backups all the data in real-time, and analyses the transmitted data.

Step 5. The Web server Nginx and application server are deployed at the remote cloud data center for users to access the online data portal of the CDMS through the browser.

Using this architecture, all valid historical data of poultry farms can be stored to the remote cloud data center. Large server clusters are not required on local chicken farms. Authorized users can access the online data portal of the system through browsers at any time.

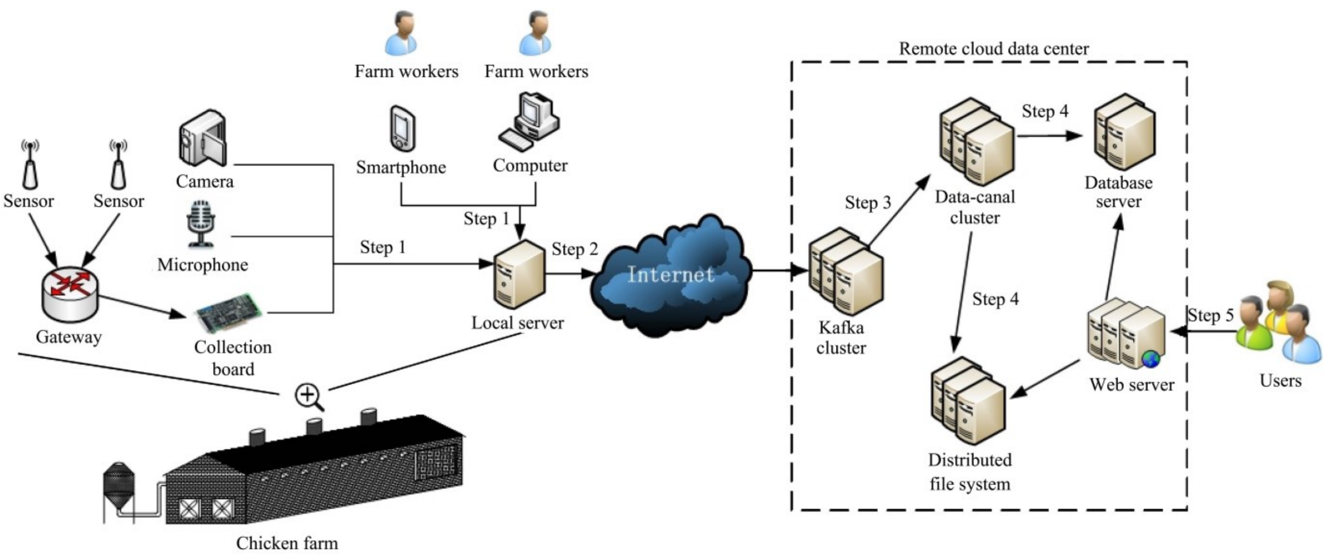

Figure 2 System architecture of CDMS

3 Data acquisition

There are two main types of data stored in the system: real-time data collected automatically with sensors and data collected manually.

3.1 Real-time data

There are three kinds of real-time data, including environmental data, audio and video data, and utility data of water and electric power used. The environmental data may include temperature, relative humidity, illumination, carbon dioxide, ammonia and wind speed. The Environmental monitoring indicators of the sensor used are shown in Table 1.

The accuracy of the data depends on the accuracy and maintenance of the sensors. All sensors are maintained periodically, including weekly cleaning and six-month calibration.

Real-time data acquisition software has a Client/

Server structure, and it is developed with software LabView[23]. The default sampling frequency of collecting the environmental data is set at once per minute, and is changeable by the user. Different acquisition frequencies during different parts of the day are used in the collection of audio and video data. At night (from 21:00 to 05:00 of next day) the software collects audio data continuously but captures one picture every 30 minutes. During daytime (from 05:00 to 21:00) it captures one picture every 2 s. Files for captured audio and video data are named by the timestamp. Limited by the network bandwidth, it is impossible to transfer all the audios and images to the remote server. The image and audio analysis software, deployed on the local server of each farm, analyses all the collected image and audio files[24,25]. Only valid files are transferred to the remote server.

Table 1 Environmental monitoring indicators

Measured elements	Measuring range	Resolution	Accuracy
Temperature/℃	0-50	0.1	±0.5℃ (0℃-50℃)
Relative Humidity/%	0-100	1	±3%(5%-95% at 25℃)
Illumination/lx	20-5000	1	<±1%
CO_2/ppm	0-2000	1	±40 ppm+3% rdg
Wind speed/m·s^{-1}	0-50	0.1	±(0.2 m/s+3% m.v.)
NH_3/ppm	0-100	1	±3% (full scale)

In order to trace the source of the data, the system automatically records the related information of acquisition location, acquisition time and acquisition sensor. To prevent information loss during data analyzing or processing, an automatic back-up was used in the system. Automatic data acquisition software saves manpower, makes farm management more efficient, and improves data quality and completeness.

3.2 Manually filled data

Farm staff completes various reports every day, such as daily sheets, equipment maintenance records, immunization records, and so on. These sheets and records mainly contain production information. Most of the reports are recorded in papers or excel files. All reports are digitized and stored in the CDMS. CDMS also provides app, which enables the staff to operate the system anywhere on the farm with a mobile phone. Computers or mobile phones are used to submit the manually collected data to the system (Figure 3).

Figure 3 APP of CDMS

4 Data transmission

4.1 Network environment

Nowadays, internet infrastructure of chicken farms has still not been fully developed in some remote regions. There are two types of networks: farmer's own private wired network which has a relatively low bandwidth and 3G network. Both networks have low bandwidth andthe cost is high. To reduce network bandwidth and flow, an optimized solution of data transmission between each chicken farm and the remote cloud data center is required.

4.2 Extraction of incremental data

There aretwo types of chicken farms data, namely, structured data such as environmental and production data stored in the database, and unstructured data such as audio, video and pictures.

Since the data collected on chicken farms are directly sent to the data center, timeout retry and slow transfer may happen because of the limited network environment. To overcome these problems, an asynchronous method were implemented: the data will firstly been stored into the database and file system in the local server of the chicken farms, a daemon program detects the update, and the incremental data will be sent to the cloud data center asynchronously.

4.2.1 Structured data

MySQL, an open-source relational database management system, was used to store the structured data collected by sensors and workers, the binlog used in the replication of MySQL can detect the change of data. The master sends the change of the data in the binlog format to the slave. The framework named python-mysql-replication was used to make the daemon act as a MySQL slave which could receive the data sent by the master, and send each row to the remote cloud data center. The core code is shown below:

```
from pymysqlreplication import BinLogStreamReader
stream=BinLogStreamReader(
connection_settings=settings,
server_id=102,
blocking=True,
resume_stream=True,
only_events=[DeleteRowsEvent,UpdateRowsEvent,
WriteRowsEvent,QueryEvent],
only_schemas=[config.ONLY_SCHEMA],log_file=f,
log_pos=p)
for event in stream:
  if isinstance(event, QueryEvent):
    logger.info('scheme: %s, query: %s',
event.schema, event.query)
  elif isinstance(event, RowsEvent):
    for row in event.rows:
      msg = {'t': event.table, 's': event.schema, 'pk':
event.primary_key}
      if isinstance(event, DeleteRowsEvent):
        msg['et'], msg['r']  = 'd', row['values']
      elif isinstance(event, UpdateRowsEvent):
        msg['et'], msg['r'] = 'u', row['after_values']
      elif isinstance(event, WriteRowsEvent):
        msg['et'], msg['r'] = 'w', row['values']
    publisher.publish(msg)
  progress_info.save(stream.log_file,
stream.log_pos)
```

To reduce the network flow, the collected data will be compressed. Also, to increase the compression ratio, all data will be sent as a bundle of 20 rows in 2 min. There is a delay of up to 2 min while more network flow will be reduced.

4.2.2 Unstructured data

Unstructured data are stored in the file system, and the path to the store is '/[henhouse No.]/[date]/[timestamp]', for example, /001/20150822/0800.avi. Audios and videos will be divided by fixed segments, and each will be saved as a file named by the timestamp. Hence, to capture the change of data, directories that the files are stored in must be monitored. Scanning the directories at a regular interval to see if a new file has been created may be a method; however it has some pitfalls: First, it costs more resources while there is a latency that depends on the scan interval. Second, the implementation is more complex because the state in saving the last scan was recorded also.

Inotify framework can be used to track and monitor the change of inode in the file system. When a file or directory is created or removed, the framework will be notified. It can also get some metadata of events, such as path of the file created. Then, a registered callback function is called to handle the event.

Python-inotify, an open-source framework, was used to handle the Inotify events. In the callback function of the file creation, files containing a video or audio will be processed and sent to the remote cloud data center. The core code is shown below:

```
import pyinotify
import logging
ROOT_PATH = '/home/data/videos/'
logger = logging.getLogger('file_watcher')
publisher = FilePublisher()
class
FileChangeEventHandler(pyinotify.ProcessEvent):
  def process_IN_CREATE(self, event):
    publisher.publish(event.path, event.name)
  def main():
    watch_mgr = pyinotify.WatchManager()
    notifier = pyinotify.ThreadedNotifier(watch_mgr,
FileChangeEventHandler())
    notifier.start()
    watch_mgr.add_watch(ROOT_PATH,
pyinotify.IN_CREATE, rec=True,auto_add=True)
    logger.info('start to watch: %s', ROOT_PATH)
    while True:
    try:
     notifier.process_events()
     if notifier.check_events():
       notifier.read_events()
```

```
        except KeyboardInterrupt:
            notifier.stop()
        logger.info('end to watch: %s', ROOT_PATH)
        break
    if __name__ == '__main__':
        main()
```

Files are pre-processed before senting to the save network flow, such as data format conversion and compression.

4.3 Metadata

Metadata are required to distinguish which chicken farms sent the data or the size and time of a video when received by the cloud data center.

4.3.1 Structured data

Structured data are stored in MySQL. The method described above is used to fetch each row created or updated. For each row, JSON format is used to serialize the data to a string. Metadata are also added to the JSON and the code is shown below.

```
{
 'time': 1440337177,
 'factory_no': 'sz001',
 't': 'sensor_data',
 'pk': 'id',
 'op_type': 'insert',
 'row': {
     'id': 1045001,
     'temperature': 26.8,
     'humidity': 42.4,
     ……
 }
}
```

4.3.2 Unstructured data

Video and audio data are in binary format and were processed as a stream. The data were divided into two parts, message header and body. The metadata are used as a header while the data as the body (Figure 4).

Figure 4 Message format of unstructured data

Metadata in the header is serialized in JSON. An example is as follows:

```
{
 'factory_no': 'sz001',
 'timestamp': 1440337177,
 'duration': 900,
 'layer_hourse_no': '001'
}
```

4.4 Distributed data transfer

Kafka was used to transfer data between chicken farms and the remote cloud data center. Four Kafka nodes were deployed in the remote cloud data center. With distributed deployment, the throughput of the system is increased substantially and single-point failures can be avoided.

There are four kinds of data transmitted by Kafka, i.e. sensor data, audio, picture and video. Each type of data is a Topic in Kafka. To balance the load, every Topic has 8 partitions distributed evenly among the nodes.

Each chicken farm is represented by a producer who sends data to Kafka cluster at the cloud data center. For each dataset, the publisher program chooses a node as a receiver. Two ways can be used: One is parting the data by the numbers of chicken farms, and the other using Round-Robin. The later method was selected in our system for two reasons: First, the load balancing is maximized, and second, the order of the data for a chichen farm is not required.

5 Data processing

When the data are transferred to the remote cloud data center through the Kafka cluster, Data-Canal independently developed by our research team[26] was deployed to process the data, it is a distributed computing framework for data stream. The mode of Data-Canal is to control flow concentration and data flow dispersion. The intermediate results are stored in a distributed file system to ensure reliability. The framework consists of Task Manager which is used to manage Task, Worker which is used to handle different Tasks, the entrance of Data-Canal Bundler, which is used to pack the real-time data flow into one task and File Deleter, which is used to remove the intermediate temporary files, when the Task is successfully processed.

The main data processing is as follows: First, Data-

Canal saves the structured data, namely data stored in the local farm server's database, to the database in the remote cloud data center. Second, Data-Canal saves pictures, audios and videos unstructured data to the distributed file system. The distributed file system is composed of Hadoop Distributed File System (HDFS), HBase, and Zookeeper. HBase is used to build a massive database for archiving all structured data. HDFS is used to store the data files of HBase, as well as unstructured data. HDFS supports disaster recovery in case a machine in the cluster breaks down, cluster recovers the data. In order to ensure the stability and data security of the system, the database is promptly backed up to the cluster. Zookeeper is a distributed coordination service, and is used to confirm HBase distributed consistency. Third, the Data-Canal backs up all the data real-time. Finally, the Data-Canal analyses the transmitted data, including statistical analysis of the environmental data and breakeven analysis.

6 Results and discussion

6.1 Online data portal

In order to display and share the data, an online data portal was developed in CDMS. The portal was based on a Brower/Server structure and used a MVC development model. With those rules, the coherence was enhanced and the coupling was reduced. To enhance the efficiency of development and the compatibility of the system, the portal used Java language as well as AJAX asynchronous transfer technology and three open source frameworks (SpringMVC, Spring, JPA), and used My Eclipse and Dreamweaver as development tools. These popular tools for development of WEB applications have great compatibility with different languages and platforms.

Authorized users enter the Uniform Resource Locator (URL) by login with username and password. They can access the website through Internet. The portal is available to all web browsers. The following graphs show two ways of displaying and sharing data. Breakeven analysis is shown in Figure 5. The cloud-based data management system calculates and summarizes daily production parameters of henhouses, and displays them on the portal. Farmers can readily see the status of the flock. Environmental data analysis is shown in Figure 6. The data can be analysed by daily, monthly or yearly. If a user needs the raw data, it can be downloaded from the portal directly. Hence, the users can clearly understand the environmental conditions of the farm through data visualization.

6.2 System performance

The system was deployed at the Shangzhuang Experiment Station of China Agricultural University, Yanqing DQY chicken farm (a commercial egg farm), and Huangshan DQY chicken farm (another commercial egg farm). The CDMS runs on top of 8 nodes in the China Agricultural University Network Center. As shown in Figure 7, the peak of data traffic occurs in daytime, because technology of different acquisition frequencies in different times was used. The throughput is up to 1036 MB/min.

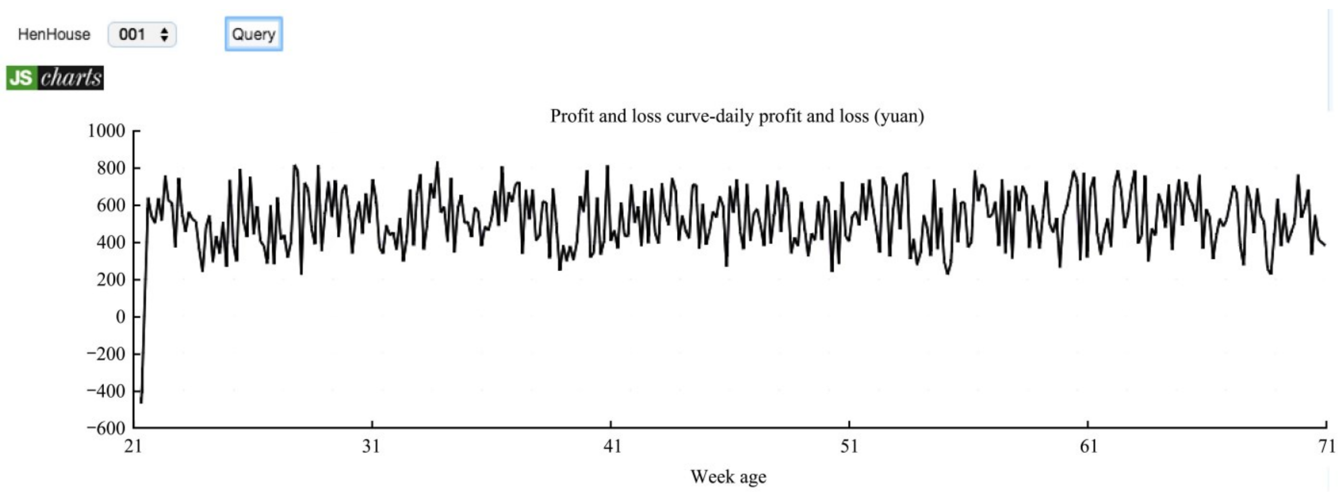

Figure 5 A snapshot of daily profit and loss for the henhouse.

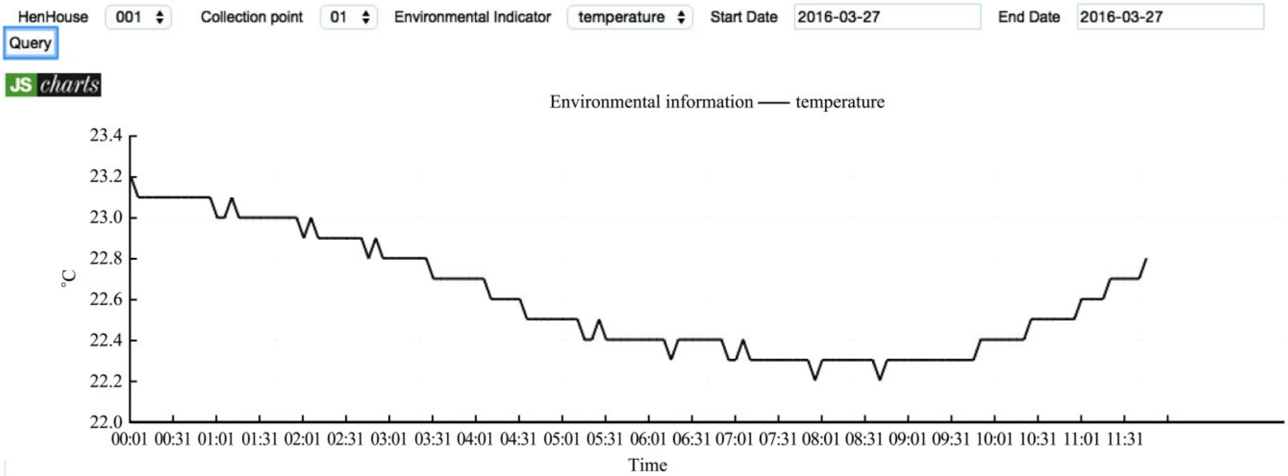

Figure 6 A snapshot of the henhouse temperature

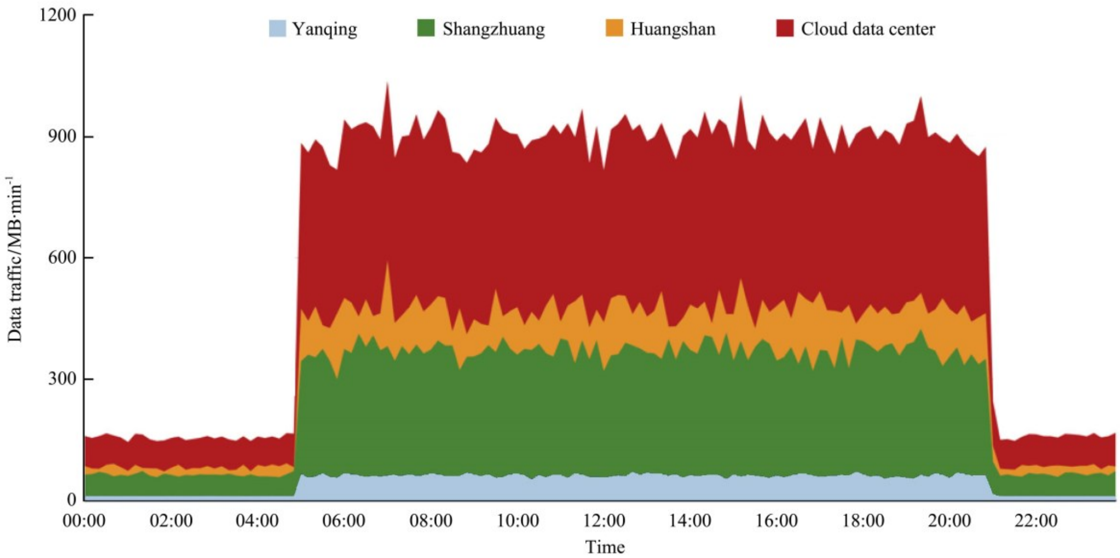

Figure 7 An example of throughput of system

7 Summary and conclusions

A cloud-base data management system (CDMS) for automated data collection from large-scale laying-hen farms was proposed in this research. The system has the following features:

(1) It is based on a distributed architecture and supports management of remote farms. In order to distinguish the data source, the system uses metadata technology. The labor force is reduced by automating the data acquisition. Workers can also use website or mobile client to submit reports and digitalized production data.

(2) An asynchronous method was implemented to overcome the problem of possible data loss. Since the data collected from the farms are directly sent to the remote data center, timeout retry and slow transfer may happen because of the limited network environment. The data will be stored into the database and file system in the local server of individual farms. A daemon program detects the update. The incremental data is sent to the remote cloud data center asynchronously. Subsequently, Data-Canal is deployed on the remote cloud data center for real-time data processing. The use of distributed file system as the intermediate results of the storage enhances the reliability of the system.

(3) The cloud provides a platform for many different farms to share the information technology infrastructure. Product information is stored in the cloud, allowing granted users to access. The online data portal of the system is based on Brower/Sever mode and can be extended in the future. It is convenient to maintain and upgrade the system. Developers update the program of the server so that the users access the latest system.

Users do not have to install any software. They can access the online data portal through the browser at anytime and anywhere in the world.

Implementation of this IT system is expected to significantly advance the ability of modern poultry producers in their efficient management of big data, record-keeping, and real-time visualization of the flock performance and housing conditions. This user-friendly management tool will further contribute to improved animal well-being, production performance, efficiency in the use of natural resources, and ultimately enhance sustainability of the industry.

Future work will consider not only managing current environmental data and production data, but also adding other physiological data such as blood pressure, heart rate, and so on. The system can provide a reference for the design and implementation of other livestock farming systems. However, according to the different demands, different types of data will be collected, analysed and managed.

Acknowledgements

The financial support was provided by the "12th Five-Year-Plan" for National Science and Technology for Rural Development in China (No. 2014BAD08B05).

[References]

[1] Aydin A, Bahr C, Berckmans D. A real-time monitoring tool to automatically measure the feed intakes of multiple broiler chickens by sound analysis. Computers and Electronics in Agriculture, 2015; 114: 1–6.

[2] Wang C S, Li J X, Huang R L, Lü J X, Li L H. Design and implementation of automatic monitoring system for layers production parameters. Transactions of the CSAE, 2014; 30(16): 181–187. (in Chinese with English abstract)

[3] Zaninelli M, Costa A, Tangorra F M, Rossi L, Agazzi A, Savoini G. Preliminary evaluation of a nest usage sensor to detect double nest occupations of laying hens. Sensors, 2015; 15(2): 2680–2693.

[4] Sales G T, Green A R, Gates R S, Brown-Brandl T M, Eigenberg R A. Quantifying detection performance of a passive low-frequency RFID system in an environmental preference chamber for laying hens. Computers and Electronics in Agriculture, 2015; 114: 261–268.

[5] McCarthy U, Brennan L, Ward S, Corkery G. Enhanced efficiencies in the poultry industry via real-time monitoring and cloud-enabled tracking. The 6th European Conference on Precision Livestock Farming, 2013; pp.212–222.

[6] Aydin A, Cangar O, Ozcan S E, Berckmans D, Bahr C. Application of a fully automatic analysis tool to assess the activity of broiler chickens with different gait scores. Computers and Electronics in Agriculture, 2010; 73(2): 194–199.

[7] Wang L F, Lu C H, Hu Y N. Implementation of computerized information management network system on 200000 Layer Farm. Transactions of the CSAE, 1999; 15(4): 207–211. (in Chinese with English abstract)

[8] Lu C H, Wu Z M, Wang L F, Hu Y L, Lu Q W, Dou S C, et al. Establishment and application of computerized production management system for large scale poultry farm. Transaction of the CSAE, 2003; 19(6): 256–259. (in Chinese with English abstract)

[9] Yu L, Teng G, Li B, Zhang Y, Lao F, Xing Y. A remote-monitoring system for poultry production management using a 3G-based network. Applied Engineering in Agriculture, 2013; 29(4): 595–601.

[10] Banhazi T M, Babinszky L, Halas V, Tscharke M. Precision Livestock Farming: Precision feeding technologies and sustainable livestock production. Int J Agric & Biol Eng, 2012; 5(4): 54–61.

[11] Berckmans D. Basic principles of PLF: gold standard, labelling and field data. The 6th European Conference on Precision Livestock Farming, 2013; pp.21–29.

[12] Banhazi T M, Lehr H, Black J L, Crabtree H, Schofield P, Tscharke M, et al. Precision livestock farming: An international review of scientific and commercial aspects. Int J Agric & Biol Eng, 2012; 5(3): 1–9

[13] Zhou X Y, Sun Z H, Zhang B L, Yang Y D. A Fast outlier detection algorithm for high dimensional categorical data streams. Journal of Software, 2007; 18(4): 933−942. DOI: 10.1360/jos180933. (in Chinese with English abstract)

[14] Jin C Q, Qian W N, Zhou A Y. Analysis and management of streaming data: A survey. Journal of Software, 2004; 15(8): 1172–1181. (in Chinese with English abstract)

[15] Plimpton S J, Shead T. Streaming data analytics via message passing with application to graph algorithms. Journal of Parallel & Distributed Computing, 2014; 74(8): 2687–2698.

[16] Guo X, Zheng L H, Li M Z, Zhang Y. Intelligent data acquisition and cloud services for apple orchard. Int J Agric & Biol Eng, 2014; 7(2): 146–153.

[17] Weng S J, Gotcher D, Wu H H, Xu Y Y, Yang C W, Lai L S. Cloud image data center for healthcare network in Taiwan.

J Med Syst, 2016; 40(4): 89. DOI: 10.1007/s10916-016-0430-8.

[18] Das K. The Internet of Things: A survey. Computer Networks, 2010; 54(15): 2787–2805.

[19] Kaloxylosa A, Eigenmannc R, Teyed F, Politopouloue Z, Wolfertf S, Shrankg C, et al. Farm management systems and the future internet era. Computers and Electronics in Agriculture, 2012; 89(5): 130–144.

[20] Vlajic N, Stevanovic D, Spanogiannopoulos G. Strategies for improving performance of IEEE 802.15.4/ZigBee WSNs with path-constrained mobile sinks. Computer Communications, 2011; 34(6): 743–757.

[21] Kaloxylosa A, Groumasb A, Sarrisb V, Katsikasb L, Magdalinosb P, Antoniouc E, et al. A cloud-based farm management system: Architecture and implementation. Computers and Electronics in Agriculture, 2014; 100(2): 168–179.

[22] Li K, Deolalikar V, Pradhan N. Big data gathering and mining pipelines for CRM using open-source. IEEE International Conference on Big Data (Big Data), 2015; 2936–2938.

[23] Jia Z C, Hu Z X, Shi X J. Study of remote monitoring and maintenance guiding technique based on LabVIEW for machining centers. Journal of Donghua University, 2005; 22(5): 29–33. (in Chinese with English abstract)

[24] Lao F D, Teng G H, Li J, Yu L G, Li Z. Behavior recognition method for individual laying hen based on computer vision. Transactions of the CSAE, 2012; 28(24): 157–163. (in Chinese with English abstract)

[25] Cao Y F, Chen H Q, Teng G H, Zhao S M, Li Q W. Detection method of laying hens’ vocalization based on power spectral density. Transactions of the CSAM, 2015; 46(2): 276–280. (in Chinese with English abstract)

[26] Chen H Q, Teng G H, Qiu X B, Meng C Y, Cao Y F, Wang C. A real-time monitoring and early warning system based on stream computing for laying hens raise. Transactions of the CSAM, 2016; 47(1): 252–259. (in Chinese with English abstract)