

## STUDIES ON VISUALIZATION OF USER LOCATION HISTORY AND USAGE STATUS IN CAMPUS WIRELESS LAN SYSTEM

HIROSHI SHIRATSUCHI<sup>1</sup>, KOZO HORIUCHI<sup>2</sup> AND TAKANORI MATSUZAKI<sup>1</sup>

<sup>1</sup>Graduate School of Humanity-Oriented Science and Engineering  
Kindai University  
11-6 Kayanomori, Iizuka-shi, Fukuoka 820-8555, Japan  
sira@fuk.kindai.ac.jp

<sup>2</sup>Gururi Co., Ltd.  
2-1-6 Uomachi, Kokurakita-ku, Fukuoka 802-0006, Japan

Received July 2018; accepted October 2018

**ABSTRACT.** *The movement to open service of the university wireless LAN system is expanding in universities with the spread of digital contents and BYOD (Bring Your Own Device). This paper proposes a method for periodically stored information of client terminal and connected user information based on the wireless LAN controller using SNMP in campus wireless LAN system. This system is also aimed to construct an Integrated Network Management System (INMS) that visualizes user connection status, and location history information for each access point, floor, and building.*

**Keywords:** Network management, Wireless LAN statistics, User location history

**1. Introduction.** According to a statistics by the Ministry of Internal Affairs and Communications in Japan, the spread of smartphones is progressing rapidly such as 56.8% for all generations and over 90% under 30 years old in 2016. In addition, the network traffic of the Internet has also increased about five times over compared to 2012. Also, in the smartphone owner of under twenty years generations, the usage time of a day is over 3 hours on weekdays, furthermore, is over 6 hours on holidays. These results become a much longer time than the average usage time of personal computers in the same generation [1].

As the rapid spread of smartphones, various techniques for speeding up mobile data communication have been introduced. However, since the major cellular phone carrier could not endure the increase rapidly in communication traffic at the backbone side, the communication fee system has shifted from the flat rate system to the measured rate system based on communication traffic. For this reason, it is necessary to reduce the amount of mobile data communication by utilizing public wireless LAN, official wireless LAN service in enterprises and schools, and the like. Various SNS services and Web sites become to provide high-quality contents utilizing high-definition images and moving images as the Internet speeds up. At university, educational contents are being digitized by using LMS (Learning Management System) to distribute lecture materials, submit reports, and online examination. In addition, the development of MOOC (Massive Open Online Course) that combines LMS and SNS, electronic store, video site and so on is proceeding as well. The Internet sites of Udacity [2] or Coursera [3] are famous for such examples. And, as campus wireless LAN became open to students, content became available for viewing by student's private smartphone.

In the case of wireless LAN connection at university, the education system user ID and password are generally used in the authentication. After the registration is completed,

the devices which enter the service provided area are automatically connected to the campus wireless LAN. Therefore, the student smartphones are always connected to the campus network while they are in the university. However, in practice, the amount of traffic unrelated to education tends to increase. This becomes a problem affecting the core communication traffic within the university. Actually, several universities have restricted certain communications to work around this problem.

On the other hand, as mentioned above, the number of smartphones and laptop computers that are brought into the university as BYOD (Bring Your Own Device) has increased rapidly. However, there is a problem that it is difficult to accurately manage information on the number of terminals, OS type, usage situation, and the like. Although computer clients used by teachers and staff need to be registered in advance, students are only user authentication from the viewpoint of convenience.

In general, Wireless LAN Controllers (WLC) have functions of adjusting the radio field intensity to equalize for each Wireless AP (Access Point) the number of connected users and distributing users. However, when designing a wireless AP deployment based on the area coverage rate, the placement plan depends on the radio wave intensity rather than the user density. Therefore, when the user gathers in a specific area, congestion occurs due to the limitation of the number of neighboring wireless APs. Moreover, such a situation cannot make clear unless a detailed connection log analysis is performed, and it is difficult to grasp the problem. In particular, since the number of users in each lecture hall of the university depends on the lecture schedule and the number of students, its analysis is difficult. On the other hand, a method of estimating position information of a user connected to a campus wireless LAN based on preliminarily prepared wave strength map information and a method of acquiring movement information from a plurality of wireless APs have also been studied [4, 5, 6].

In this paper, a method of periodically collecting information of the client terminals and connected users from campus wireless LAN controller by using SNMP (Simple Network Monitoring Protocol) is proposed. Namely, it is aimed to construct an Integrated Network Management System (INMS) that visualizes user connection status and information for each access point, floor, and building. By visualizing the connection status, it is considered that the validation of the placement of the access point can be analyzed. Furthermore, it is also possible to identify the location that causes congestion.

Also, since most students move around the campus with their smartphones, they are always connected to one of the APs. Therefore, by periodically recording the list of connected terminals of wireless APs, it is possible to generate student's location history. Thus, even if there is no special device, user location history information in the campus can be collected. Furthermore, it becomes possible to extract the behavior of the student by visualizing the user location history. And it becomes possible to create a lecture timetable in consideration of the flow of students and to provide new services utilizing location history information.

**2. Overview of Campus Wireless LAN System.** In this section, the outline of our campus wireless LAN system is described. Figure 1 shows a connection overview diagram, and each wireless AP is arranged to cover the entire area based on the result of electric field strength investigation in the campus. Moreover, the wireless APs are centrally managed by the Wireless LAN Controller (WLC). When a client terminal such as a smartphone connects to a wireless AP, it tries to connect to an access point identification name called SSID (Service Set Identifier). Then, in the IEEE 802.1x authentication method, it is possible to connect as an authenticated user by sending and receiving an EAP (Extended Authentication Protocol) message to the RADIUS server.

In our university, the equipment configuration is operated as shown in Table 1, and wireless accesses in almost all campus areas are available.

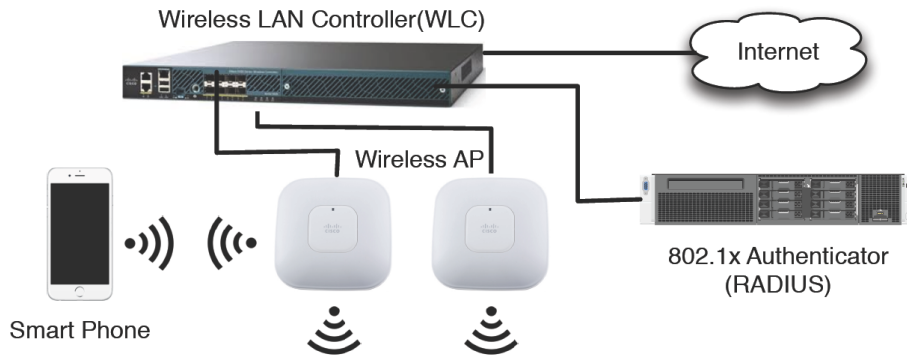


FIGURE 1. Overview of campus wireless LAN system

TABLE 1. Configuration of campus wireless LAN system

Role	Device name	Number of devices
Wireless AP	Cisco Aironet 1600 etc.	about 100
Wireless LAN Controller	Cisco 5500 WLC	3
RADIUS Server	CentOS (Virtual Machine)	3

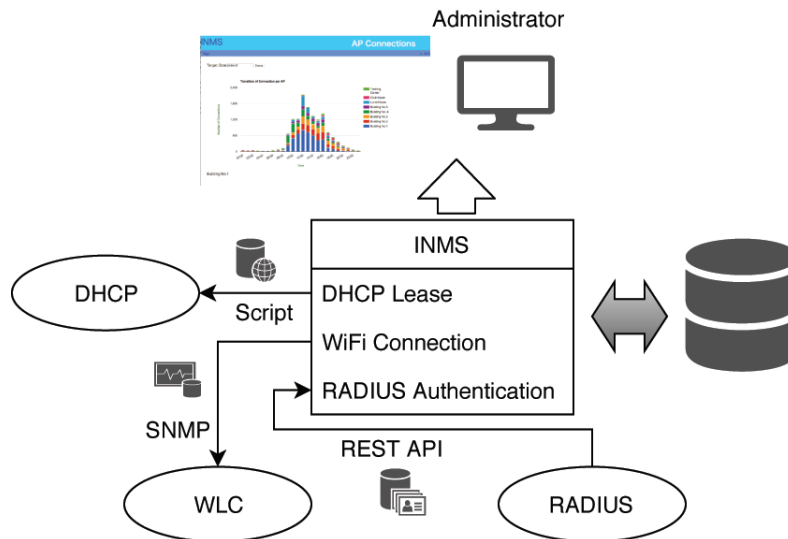


FIGURE 2. Overview of the proposed INMS

**3. Proposed Integrated Network Management System (INMS).** In our previous development, an Integrated Network Management System (INMS) for comprehensive managing various network devices installed in the rooms for teacher, staff, laboratory and computer exercise is developed and operating as a web application. That is, INMS can receive the requests for the campus network connection, and automatically assigns VLANs and IP addresses according to information such as the model name, MAC address, and room number, of computer equipment input there. Therefore, it is possible to acquire the state of all the devices connected to the campus network in real time. In this section, the extended modules that collect statistical information of wireless terminals for INMS previously developed for only wired networks are developed.

Figure 2 shows an overview of the proposed INMS wireless client management function part. As shown in the figure, firstly, INMS periodically collects the connected client information from the WLC using SNMP and stores these in the database. Then, from the DHCP (Dynamic Host Configuration Protocol) server, lists of IP addresses assigned to

the client terminal and the authentication log from the RADIUS (Remote Authentication Dial In User Service) server are acquired. This information is stored in the database after associating the MAC address of the client with the OID (Object ID). Therefore, by accessing the INMS, the administrator can browse the information such as the connection information and the usage rate of the access point via the Web browser.

**4. Development Specification of the Proposed System.** The WLC operated by our university can periodically acquire connected client information of all wireless APs by SNMP. Namely, the extended MIB (Management Information Base) information as shown in Table 2 is designed to acquire about every 5 minutes. Although various information can be acquired by SNMP, only two MAC information of connection client and destination wireless AP is required as time series data in the proposed system. Therefore, in order to associate the above information with the connected user, first, the combination information of “connected username” and “connected client MAC” is collected from the RADIUS server. Regarding the frequency of inquiries to the RADIUS server, in general, the user terminal thinks that it is unnecessary to consider changes and new additions on a daily basis, and runs the script on the server around 1:00 every day to consolidate the previous day. The INMS is stored in the database after receiving this information by polling script. Furthermore, it acquires the correspondence table of the allocated MAC address and IP address from DHCP (Dynamic Host Configuration Protocol) server and saves it in the database. Each procedure is described in detail in subsequent paragraphs.

TABLE 2. Extended MIB list used in the proposed system

Extended MIB (OID)	Stored information
1.3.6.1.4.1.14179.2.1.4.1.1	Connected client MAC
1.3.6.1.4.1.14179.2.1.4.1.7	Connected SSID
1.3.6.1.4.1.14179.2.1.4.1.4	Destination wireless AP MAC
1.3.6.1.4.1.14179.2.2.1.1.1	Wireless AP’s MAC
1.3.6.1.4.1.14179.2.2.1.1.3	Wireless AP’s SSID

Tables 3(a) to 3(d) show examples of the results of collecting each MIB information shown in Table 2 from the WLC by SNMP. The MIB code and MAC information in the tables are anonymized by omitting part or putting down part since corresponding to the personal information. Various information can be acquired from each MIB, and aggregation of this information is possible by using MIB code or MAC address as a related key. Specifically, if the MIB code (underlined part) corresponding to the connection client MAC address in Table 3(a) is searched in Table 3(b), the connecting destination wireless AP MAC (double underline part) can be obtained. Furthermore, the SSID information of the wireless AP device shown in Table 3(d) can be obtained as the MIB code (wavy line) of the record that matches the MAC information (double underline) of the wireless AP device shown in Table 3(c). That is, from these four kinds of information, it is found to link that the destination wireless AP of this client terminal MAC (03:24:XX:XX:42:2A) is 4-2F-AP5.

As described above, various information can be obtained by specifying MIB. However, it is necessary for the proposed system to repeat per 5 minutes the operation of acquiring a large amount of data through SNMP and making it into a database after internal processing at periodical intervals. For the purpose of speeding up processing, only two of the client MAC and the connected wireless AP MAC are collected from the WLC as time series data. Then, other information not requiring real-time property is gathered timely. Through the above procedure, large-scale connection history information is efficiently stored in a database.

TABLE 3. Examples of SNMP informations from the wireless LAN controller

(a) Example of obtaining connected client MAC information by SNMP

---

SNMPv2-SMI::2.1.4.1.1.0.36.165.148.66.42	=	03:24:XX:XX:42:2A
SNMPv2-SMI::2.1.4.1.1.0.36.165.148.67.19	=	30:14:XX:XX:43:DB
SNMPv2-SMI::2.1.4.1.1.0.38.108.28.227.24	=	09:26:XX:XX:E3:18
SNMPv2-SMI::2.1.4.1.1.0.40.248.65.34.71	=	D0:28:XX:XX:22:47
SNMPv2-SMI::2.1.4.1.1.0.205.254.31.28.79	=	00:CD:XX:XX:1C:4F

---

(b) Example of obtaining destination wireless AP MAC information by SNMP

---

SNMPv2-SMI::2.1.4.1.1.0.36.165.148.66.42	=	<u>00:38:XX:XX:85:C0</u>
SNMPv2-SMI::2.1.4.1.1.0.36.165.148.67.19	=	00:56:XX:XX:17:50
SNMPv2-SMI::2.1.4.1.1.0.38.108.28.227.24	=	00:5D:XX:XX:40:20
SNMPv2-SMI::2.1.4.1.1.0.40.248.65.34.71	=	00:5D:XX:XX:40:A0
SNMPv2-SMI::2.1.4.1.1.0.205.254.31.28.79	=	00:5D:XX:XX:41:00

---

(c) Example of obtaining wireless AP's MAC information by SNMP

---

SNMPv2-SMI::2.2.1.1.1.0.56.223.94.33.192	=	<u>00:38:XX:XX:85:C0</u>
SNMPv2-SMI::2.2.1.1.1.0.86.43.253.23.80	=	00:56:XX:XX:17:50
SNMPv2-SMI::2.2.1.1.1.0.93.115.252.64.32	=	00:5D:XX:XX:40:20
SNMPv2-SMI::2.2.1.1.1.0.93.115.252.64.60	=	00:5D:XX:XX:40:A0
SNMPv2-SMI::2.2.1.1.1.0.93.115.252.65.0	=	00:5D:XX:XX:41:00

---

(d) Example of obtaining wireless AP's SSID information by SNMP

---

SNMPv2-SMI::2.2.1.1.3.0.56.223.94.33.192	=	<span style="border: 1px solid black; padding: 2px;">"4-2F-AP5"</span>
SNMPv2-SMI::2.2.1.1.3.0.86.43.253.23.80	=	"1-2F-AP3"
SNMPv2-SMI::2.2.1.1.3.0.93.115.252.64.32	=	"2-2F-AP9"
SNMPv2-SMI::2.2.1.1.3.0.93.115.252.64.60	=	"5-2F-AP3"
SNMPv2-SMI::2.2.1.1.3.0.93.115.252.65.0	=	"5-3F-AP3"

---

TABLE 4. Example of obtaining user information from the RADIUS

RADIUS log	Extracting information
Mon Apr 23 10:00:18 2018: Auth: Login OK: [user01] (from client fuk-kindai port 13 cli 00-26-XX-XX-db-12)	user01, 00:26:XX:XX:db:12
Mon Apr 23 10:48:35 2018: Auth: Login OK: [user02] (from client fuk-kindai port 18 cli 00-50-XX-XX-9e-d1)	user02, 00:50:XX:XX:9e:d1
Mon Apr 23 16:04:03 2018: Auth: Login OK: [user03] (from client fuk-kindai port 21 cli 12-7e-XX-XX-f0-c1)	user03, 12:7e:XX:XX:f0:c1

This is because the time variation of the access point name and connected user information is small and the information obtained from the WLC is only information at the time of SNMP connection, so duplication or missing of information occurs. For this reason, the access point name is appropriately updated when access point addition or repair occurs. In addition, the connected user information is designed to be acquired from the RADIUS server in the form shown in Table 4, every day at 0:00. Specifically, the connection log is analyzed on the RADIUS server, and the list of all connected users on the previous day is generated in the JSON format. Afterwards, they are transferred by the REST API provided by INMS. Furthermore, the IP address assignment lists are stored in the form shown in the inquiry Table 5 to the DHCP server every 4 hours which is the lease time limit.

TABLE 5. Example of extracting information from DHCP server's lease log

DHCP lease log			Extracting information	
172.18.64.1,	2018-04-23	10:48:23,	LEASE,	03:24:XX:XX:42:2A, 172.18.64.1
03:24:XX:XX:42:2A, myPhone				
172.18.64.2,	2018-04-20	16:28:13,	FREE,	30:14:XX:XX:43, 172.18.64.2
30:14:XX:XX:43:DB, MyAndroid				
172.18.64.3,	2018-04-23	10:53:45,	LEASE,	09:26:XX:XX:E3:17, 172.18.64.3
09:26:XX:XX:E3:17, iPhone				

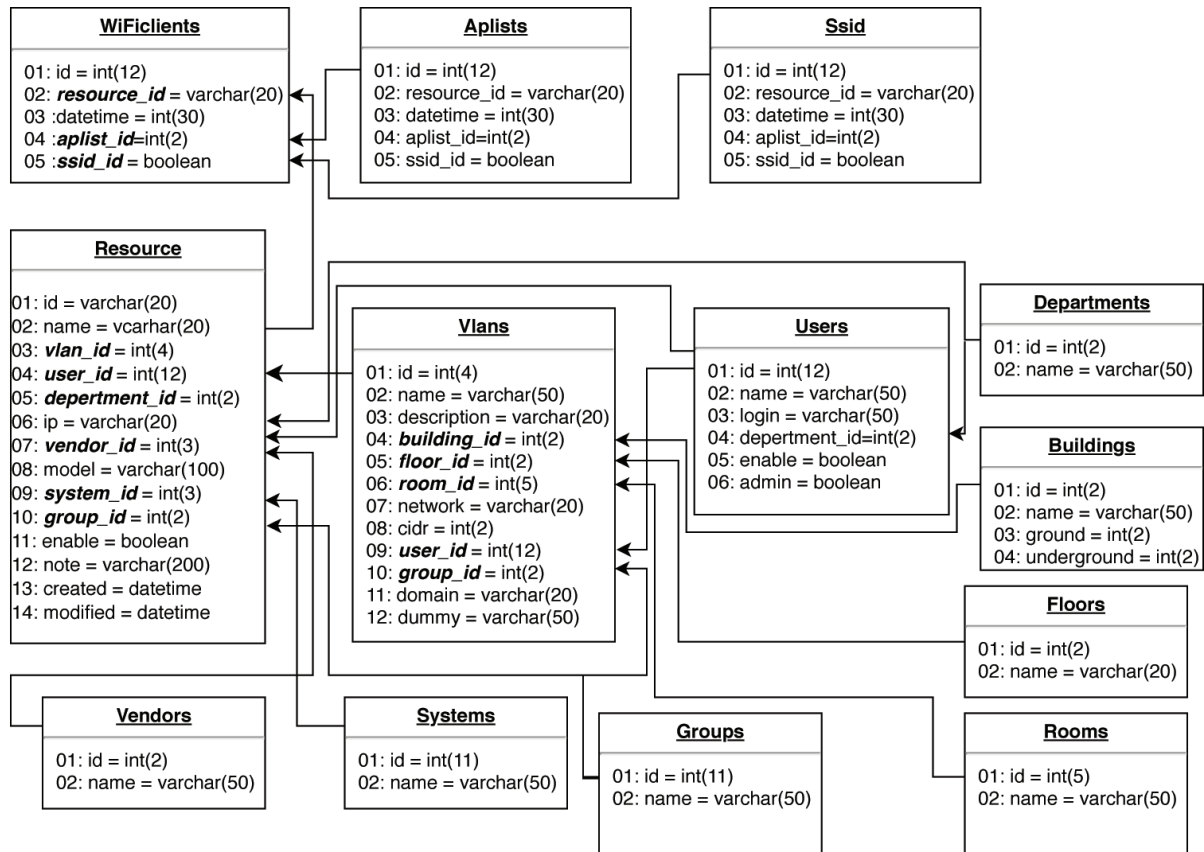


FIGURE 3. Database structure of the proposed system

**5. Example of Operation of the Proposed System.** After analyzing the information stored in the database (Figure 3), they are visualized as graphs or figures using Google Charts API [7]. In other words, it is constructed as the Web application which can display the time transition of the number of connected users for each building and floor as a graph. Figure 4 shows a connection number transition information graph for each hour of a certain day. In the figure, the date selection portion is shown on the upper left, the time on the horizontal axis of the graph and the number of connections on the vertical axis are color coded for each building and displayed as a stacked graph. From this figure, it is possible to visually read the transition of the number of connections. In addition, it is possible to display the number of connections by floor in each building, and it is also possible to visualize the actual use situation of the lecture building and research.

Since the connection history information of each wireless AP is recorded at intervals of 5 minutes, it is also possible to visualize the personal location history. Figure 5(a) shows a one-day location history of a student. In the figure, the horizontal axis represents time and the vertical axis represents the connection location. The size of the circle represents

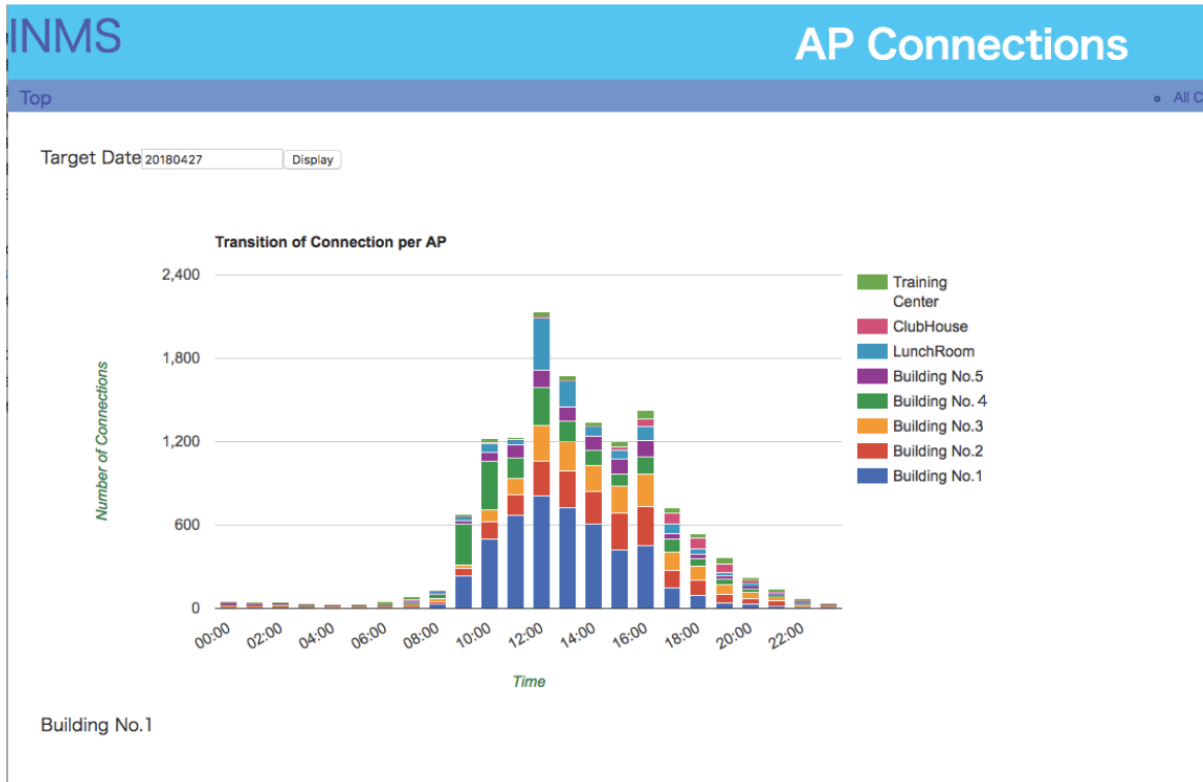


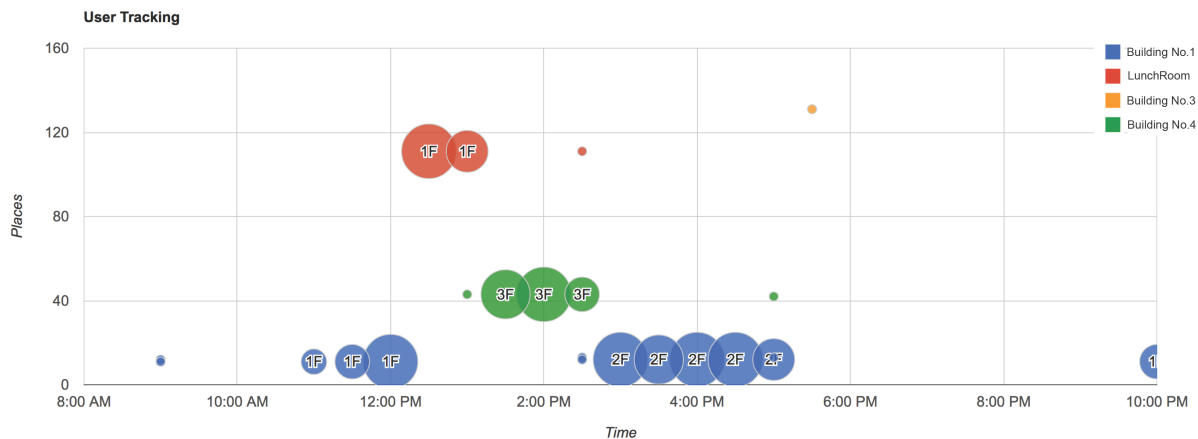
FIGURE 4. (color online) Time series display of the number of connections for each building by the proposed method

the number of wireless AP connection times, the color indicates the building number, and the text indicates the floor number. From the figure, it is found that this student arrived at the university around 10:30 and attended the lecture room for the second period, returned to the lecture building again after taking lunch at lunchroom and studying at the computer center.

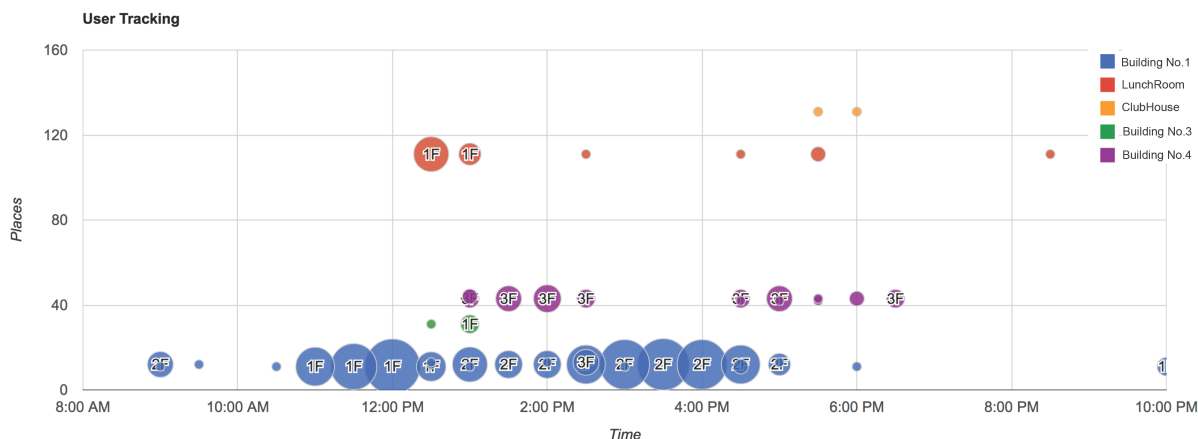
Furthermore, Figure 5(b) shows the result of aggregating user location history of the same day of the week throughout a month. From this figure, regarding this day of the week, it is seen that the user location history is almost the same as in Figure 5(a). Also, it is found that there is a tendency to learn self-study at the computer center after school hours and after school.

**6. Conclusions.** In this paper, an Integrated Network Management System (INMS) for aggregating usage information of users connected to campus wireless LAN was developed. In other words, by linking client terminal information connected to each wireless AP with connected user information and recording it as a database, a system to visualize usage statistical information of wireless AP and user location history of the user is developed as a web application. From the analysis by using real WiFi connection history data, it was confirmed that the proposed system can realize the time series visualization for distribution of client connections and personal location information.

In the future, it will be analyzed as the basic information for improvement of campus wireless LAN by utilizing the collected data. In addition, by analyzing user location history information using deep learning, it will be studied various developments such as aiming to extract student behavior pattern indexes.



(a) User location history's results for a day



(b) User location history by same a day of week in a month

FIGURE 5. (color online) Extraction user location history from real WiFi connection data

## REFERENCES

- [1] *WHITE PAPER 2017 – Information and Communications in Japan*, Ministry of Internal Affairs and Communications, Japan, 2017.
- [2] *Udacity: Free Online Classes & Nanodegrees*, <https://www.udacity.com/>.
- [3] *Coursera: Coursera Provides Universal Access to the World's Best Education*, <https://www.coursera.org/>.
- [4] A. Kirmse, T. Udeshi, P. Bellver and J. Shuma, Extracting patterns from location history, *International Conference on Advances in Geographic Information Systems (ACM SIGSPATIAL GIS)*, <http://www.sigspatial.org/>, pp.397-400, 2011.
- [5] W.-C. Lu, Y.-C. Cheng and S.-H. Fang, A study of singular value decomposition for wireless LAN location fingerprinting, *Proc. of the 2nd International Conference on Multimedia Big Data*, pp.466-476, 2016.
- [6] T. Ito, K. Murakami and S. Ishihara, Improving wireless LAN throughput by using concurrent transmissions from multiple access points based on location of mobile hosts, *Proc. of the 12th IEEE International Workshop on Managing Ubiquitous Communications and Services*, pp.99-104, 2015.
- [7] Google Developers, *Google Charts – Interactive Charts for Browsers and Mobile Devices*, <https://developers.google.com/chart/>, 2018.