A LOCATION-AWARE CALL FORWARDING MANAGER SYSTEM FOR A SMART TELEPHONY NETWORK OF THE SMART SPACE

Heng-Chih Huang, Yueh-Min Huang, and Kuan-Chieh Chiu

Dept. of Engineering Science

National Cheng Kung University, Tainan, 701

Taiwan, R.O.C

n9893109@ccmail.ncku.edu.tw

Abstract- A smart space, such as smart sensor rooms, an office, or simply an area, requires a smart telephony network for an effective voice communication between users. Nowadays, modern Private Branch Exchange (PBX) system does not only provide telephone exchange, but also supports many heterogeneous telephony networks and provides many other useful functions as well. Despite its powerfulness, PBX still cannot achieve a basic requirement for a smart space: It cannot adapt its surroundings automatically, i.e. people still need to make the call forwarding setting manually. In this paper, we propose a system with an algorithm named "2D location-aware" for tracking a person in a smart space. According to the ever-changing environment, the system performs an on-the-fly configuration to provide a dynamic telephony network. In other words, we aim to make all the telephones in the network available to every user in the smart space for receiving his phone calls without any manual call forwarding settings.

Index terms: Location-aware, Sensor Network, Smart Space, Smart Sensor Rooms, Real World Interaction, Call Forwarding, IP phone.

I. INTRODUCTION

Most people might have such kind of experience: try to get in touch with someone in a company by dialing its general phone number plus his extension number. After a few ring tones, the caller may only hear a voice message: "Sorry, the person you are trying to reach is not available now. Please try again later or press '0' to leave a message." After a while, the caller may be lucky enough to reach the staff by calling again and again. This indeed requires too much time to find a person. No doubt, this problem can be easily resolved by providing every staff a wireless or coreless phone and the staff could be reached under most circumstances. Apparently, however, this solution brings out many other concerns as well, such as equipment costs, battery life time, interference and handover, etc. A smart space [1], such as smart sensor rooms, simply an office, or even a whole building, is supposed to detect all the users in the space [2] and serve them. One of the important services we believe is the smart telephony network for an effective voice communication. Nowadays, modern Private Branch Exchange (PBX) [3] system does not only provide telephone exchange, but also supports many heterogeneous telephony networks and provides many other useful functions as well. Despite its powerfulness, PBX still cannot achieve a basic requirement for a smart space: It cannot adapt its surroundings automatically, i.e. people still need to make the call forwarding setting manually. Hence we propose a different solution to serve the same purpose. With our solution, our user would no longer miss a single call simply because all the telephones in the system belong to him/her.

Our proposed system will assign each employee in the company a unique extension number, say “168” for Employee A. Obviously, while he/she is working in his/her working station, its phone’s extension number is "168". Yet, he/she may leave from his/her desk for a conference room to have discussion with Employee B. Our system would then automatically instruct PBX or IP-PBX switch to reassign a new extension number “168” to the phone nearest to Employee A, i.e. the phone in the conference room. Similarly, our system would execute the same procedure for Employee B too. Thus, the system will forward all their incoming calls to the phone in the conference room and therefore, these 2 employees, even away from their working stations, will not miss a single call throughout their discussion. If no fixed phone is located around them, the system will forward their incoming calls to their cellular phones automatically.

Our system has two advantages comparing with other call forwarding systems and those are: users do not need to know any telephone number or activate the “call forwarding” service; and our system can be installed in some particular places where mobile phone is forbidden, such as a hospital.

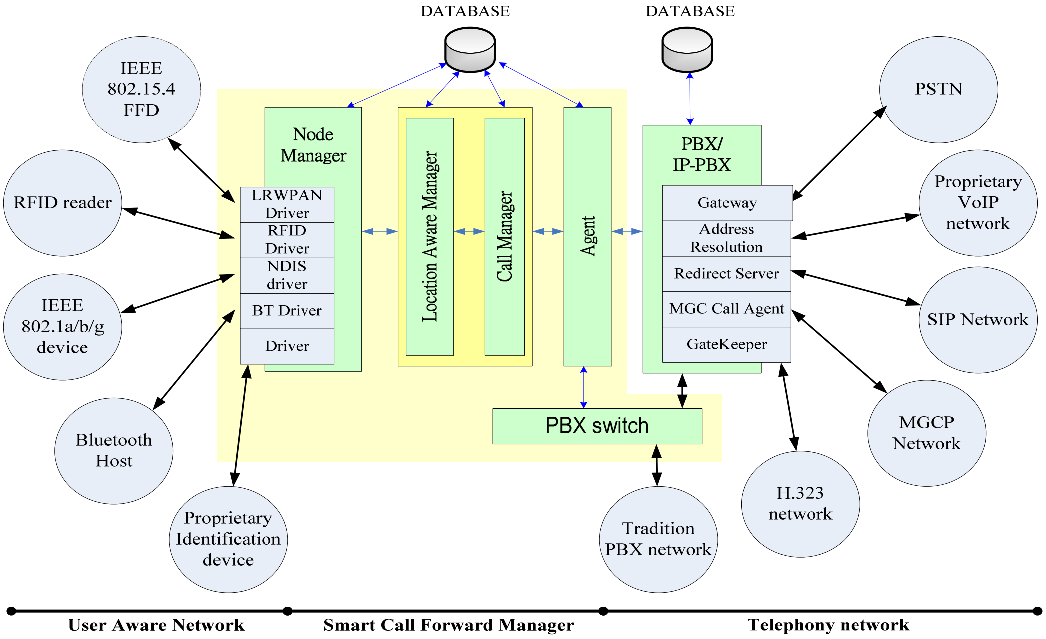

Fig. 1. System Architecture

II. THE DESIGN OF SYSTEM

The functionalities of the location-aware system for Smart Call Forwarding archives are listed below:

(1) Keeping a consistent way users are used to answering calls

(2) No complex and frequent set-up

(3) No missed call (whether or not user is in the space)

(4) Compatibility with traditional telephony network

(5) Flexible in integrating with others systems like security system

We can divide our whole system into 3 major parts: User Aware Network, Smart Call Forward Manager, and Telephony network. The whole system architecture is shown in Fig. 1. User Aware Network can adopt any wireless sensor network as long as the network can provide user's location (node or tag location). Both IP-PBX and PBX provide private telephony network. Besides, we have proposed a Smart Call Forward Manager located between User Aware Network and Telephony Network and featured by Node Manager, Location Aware Manager, Call Manager, Agent and PBX Switch. Each module in the Smart Call Forward Manager is isolated and exchanges data via a database.

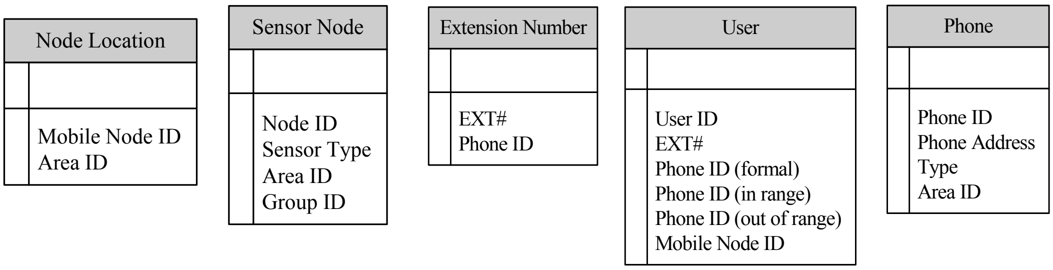

Fig. 2. Tables in the database of the system.

a. Node Manager (NM)

Node Manager handles all the various nodes' data. A user aware network has two types of node: mobile node and sensor node. In our application scenario, each node has a unique identifier, visibility radius and a coordinator. The sensor node(such as proximity card reader) requires at least one detected device called the mobile node (tag) to identify a user's location. For instance, in most offices, each staff possesses his/her own proximity ID badge for entering the office in an access control network. It can hence provide a piece of rough information about the user's location to Node Manager. In our system, the user aware network can adopt any network as long as it can provide the location or related information about the mobile nodes. In a smart space, we recommend a wireless sensor network [4] because it can be adopted more flexibly and provide more information on each node.

b. Location Aware Manager (LAM)

As the name implies, location aware manager (LAM) is responsible for identifying and recording the location of each node in the database, as shown in Fig. 2. In some node aware networks, such as wireless sensor network, its nodes cannot provide sufficient information on the mobile node's location. We hence install LAM in the network. LAM can acquire further information from the node aware network and then speculate about the mobile node's location. For example, a wireless access point [5] can recognize the radiation signal strength of any wireless communication devices connecting to it, but it does not know the devices' exact location. In such case, we use LAM as it can infer a node's location by gathering information from several access points. The algorithms for the inference will be listed at a later section.

c. Call Manager (CM)

Call Manager is a core part of our system. Our system can assign any available phones in the network to be anyone's private phone in a dynamical way. Before establishing an incoming call session for a user, Call Manager will first select a phone closest to the user, which can be a traditional PBX extension phone, IP phone, mobile phone or a PTSN phone. As soon as it has chosen a suitable phone, Call Manager will require a large amount of information to carry out a complex and dynamic mapping procedure. An example of such information tables in a database used by CM is shown in Fig. 2, too.

Table "Extension Number" is a mapping list to be generated by CM. This table contains the fields "EXT#" and "phone ID". "EXT#" stores a list of extension numbers with PBX and the field "phone ID" indicates which telephone set the user may use for answering phone calls.

Table "Phone" stores the phone addresses and the locations of all the telephones that the PBX and IP-PBX support. The phone address can be stored based on any address standard, such as ITU E.164[6], alias-address, IP address, or any standards recognized by IP-PBX or PBX-switch.

Table "User" has each user's formal extension number, mobile node ID (usually a badge ID) and three phone IDs: 1. the phone address of the telephone allocated to the user by the company, 2. the phone ID of a phone set available to the user, updated by CM according to his location, 3. a backup phone ID to be used when the user is out of working range of the node aware network. Hence, any of the above three phones will become the user's extension number depending on his location.

By applying some algorithms, CM can update the table "Extension Number" using other tables' data, such as tables "User" and "Phone". In addition, the contents of the field "Phone ID (in range)" will be changed in real time according to the table "Node Location" maintained by LAM

d. Agent

To ensure the incoming calls are being correctly forwarded, after CM has updated the mapping list, it needs to either request IP-PBX for updating its own address-mapping data or instruct PBX-Switch to perform a line switch. To ask IP-PBX for updating the data, we may 1) access the database of IP-PBX directly, 2) establish a connection for configuration with IP-PBX, or 3) use the shell commands provided by IP-PBX. We use which one of the above depending on the interface supplied by IP-PBX. Thus, the Agent is designed as an isolated program module such that we initiate different Agent for different PBX/IP-PBX system. For some traditional PBX, we require an Agent which has an additional device for lines switch because its interface has no live configuration by other devices.

III. THE ALGORITHM FOR LOCATION-AWARE FORWARDING

In this section, we will introduce the algorithms we apply in Location Aware Manager and Call Manager of the proposed system. In fact, a short range or proximity node is always in use in the node aware network because the simpler algorithms will result from its lower interference. In our proposed system, however, we will employ a middle or higher range sensor network.

a. Location-Aware Manager

The node aware manager collects the information from all the nodes and the Location-Aware Manager (LAM) transmits such information by using some graph data, as shown in Fig. 3. In Fig. 3, node M is a Mobile Node(a tag) that a user usually carries along, and node S is a sensor node in a fixed location linked to a power supply. And, LAM is responsible for locating the sensor node nearest to each mobile node. The difference between two nodes is the reference distance value, derived from the signal strength. The network can be imagined as a non-directional graph, G = (V, E) in Fig. 3. Hence, by using the Dijkstra's algorithm [7], we can calculate the single-source shortest path between sensor nodes (source vertexes) and mobile nodes (target vertexes). The shortest length of path (SLP) from vertexes x to y, denoted δ(x,y), is defined as follows:

$$\delta(x,y) = \begin{cases} \min(length(p_{xy,0}), \text{ if } p_{xy,0} \neq \phi \\ \min(length(p_{xy,n}), \text{ if } p_{xy,0} = \phi \text{ and } p_{xy,n} \neq \phi, n \geq 1 \\ \infty, \quad \text{otherwise .} \end{cases} \quad (1)$$

where $p_{xy,n}$ means the length of a path between vertex x and y via n number of vertexes, and length($p_{xy,n}$) is the sum of the weights of its constituent edges shown as below:

$$length(p_{xy,n}) = \sum_{i=1}^{n} \omega(v_{i-1}, v_i) \text{ .} \quad (2)$$

In equation (2), ω is a weight of the edge between two vertexes and n is the number of vertexes on the path between vertexes x and y. The parameter n is used for hop control. A System designer is consistent with the radio range of mobile nodes. The more number of vertexes in the path, the more complex it will become and the more memory space system it will require.

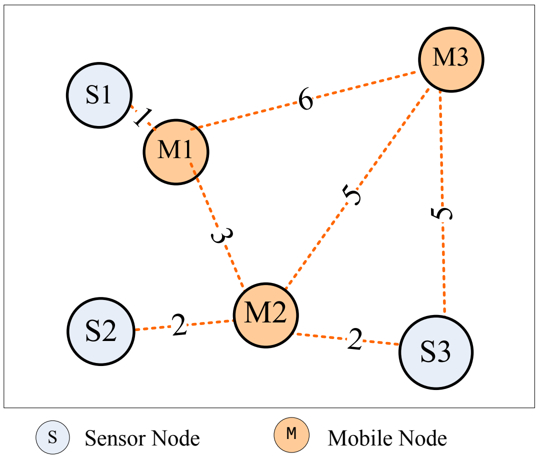

Fig. 2. An example of network represented by a weighted graph.

Table 1 shows the shortest lengths between S and M, δ(S,M) of the graph in Fig. 3, where S∈{S1,S2,S3} and M∈{M1,M2,M3}. Each single path has at most 3 vertexes (nodes) because the hop control parameter n is given by 1. Therefore, the shortest length δ(S,M1)={1,5,5} δ(S,M2)={4,2,2} and δ(S,M3)={7,7,5}. Obviously, the sensor node nearest to M1 is S1 and the node nearest to M3 is S3 in Fig. 3.

Table 1. Shortest length of vertexes in graph in Fig. 3.

Nodes		**Shortest Length**		
		Directly	*Indirectly*	*Indirectly*
S1	**M1**	1	N.A.	N.A.
	M2	N.A.	4	12
	M3	N.A.	7	9
S2	**M1**	N.A.	5	13
	M2	2	N.A.	N.A.
	M3	N.A.	7	11
S3	**M1**	N.A.	5	11
	M2	2	10	14
	M3	5	7	11

In Fig. 3, two sensor nodes, S2 and S3, have the same shortest length from the mobile node M2 at the same time. In such case, we could employ a simple arbitration algorithm to easily but effectively pick the best suitable sensor node. A sensor node will have the highest priority if it has the least number of mobile nodes nearby and therefore will be selected. In our algorithm, the priority of the sensor node is based on its ID sequence. For example, node S1 has higher priority than node S2.

With the above algorithms, LAM can find out the sensor node nearest to each mobile node. Every sensor node has an area ID. Hence, LAM can assign an area ID to every mobile node such that it has the same area ID as its nearest sensor node. For example, in Fig. 3, the shortest length δ(S,M1)={1,5,5}, so M1 and S1 has the same area ID. To keep the information accurate all the time for CM, LAM must update some data such as area IDs of the mobile nodes very frequently.

b. 2D Location-Aware Algorithm

In a space without barriers or walls, LAM can always apply the above approach to find out which sensor node closest to a mobile node, and thus locate which area the mobile node is situated. Yet, most offices contain a number of partitions to be some working stations or rooms and hence, we may have a situation as shown in Fig.4. Both S1 and S2 are sensor nodes attached to telephones, while S3 is only a wireless sensor node for access control. By applying the above algorithm, a problem arises: the system will select S2 as the suitable phone because M2's area ID is the same as S2's even though they are located in different partitions. To remedy this situation, we propose an approach "*2D location-aware*".

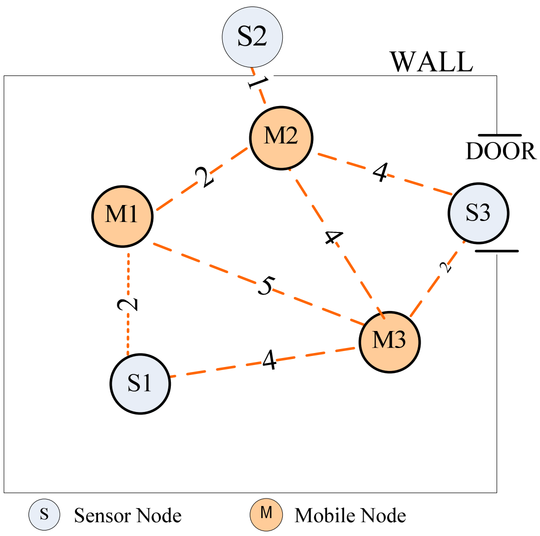

Fig. 3. An example of wrong area ID assigning to M2.

As described, due to insufficient information, CM cannot determine the mobile nodes' location(user in a partition or not) in some kinds of complex environment. Hence, we should include one more piece of information – group ID, as well.

LAM needs to record a history of the area IDs of each mobile node, including the sensor node for access control only. Moreover, in an office with partitions, we should assign all sensor nodes in a partition, including those for access control, to the same group ID. If the mobile node(the user) has entered the partition, those sensor nodes attached to the phones in the same group must have higher priority for being selected. For example, in Fig. 4, node S1 and S3 have the same group ID. And, since node M2 has entered the partition, it will have the same area ID as node S3's, and LAM will keep this in its history. During the later location updating, although the shortest path δ(S,M2) is{4,1,0}, LAM will still choose S1 as a phone to be transferred because S2 has a different group ID and the device with S3 is not a phone set. The complete algorithm in LAM is shown below:

INPUT:
1. A graph G = (V, E), where V∈{S, M}
2. A constant *n*, the limitation of number of vertex on a path.

OUTPUT:
The area ID assigned to mobile node: AreaID[m], m∈M

```
Step1: for each vertex s∈S
            for each vertex m∈M
                if type(s) =1
                    then SLP[s,m]← δ (s,m) // this sensor node belongs a phone
                    else SLP[s,m]=0

Step 2:for SLP[s,m] to each vertex m∈M
            do run MIN(SLP[s,m]) to get a vertex s∈S, where SLP[s,m]≥0
                    If GroupID[s]∈GroupID[LastSensorNodeID[m]]
            then AreaID[m]←AreaID[s]
                        add SensorNodeID[s] into LastSensorNodeID[m]
                            else SLP[s,m]← -1
            go to Step 2 //exit for-loop and reassign AreaID again
```

c. Call Manager

To a CM, a mobile node has only two statuses: 1. the mobile node can be detected by Node Manager; 2. it cannot be detected. CM is responsible to receive and analysis such information, and updates the related tables frequently. The LAM will have information on a mobile node only when it is detected. That is to say, the mobile node with no data appeared in the tables, i.e. not detected by Node Manger, is supposed to be out of the sensor network. Thus, CM will assign the ID in the field "Phone ID (out of range)" to this mobile node's mapped phone ID, as shown in the flowchart in Fig. 5.

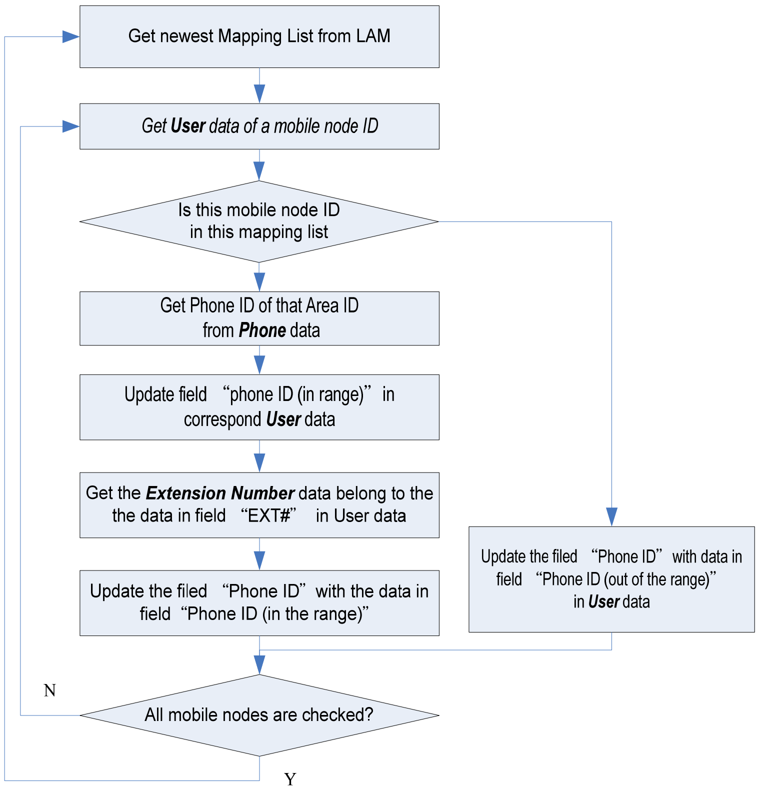

Fig. 4. The flowchart of Phone ID allotment for table "Extension Number".

IV. AN EXPERIMENT: A SMART CALL FORWARDING MANAGER SYSTEM

We have built a prototype system in our experiment shown in Fig.6. In this system, IP phone, shown in Fig. 7, is equipped with software SIP IP-PBX for providing telephone function, and LRPWAN [8]device acts as both mobile node and sensor node for constructing a sensor network.

Each user has an IP phone as his private phone with an extension number, and a LRPWAN device as his own badge. IP phone 5 is a phone in a conference room. Sensor nodes S1~S5 are close to IP phones 1~5 respectively and S6 is used for access control.

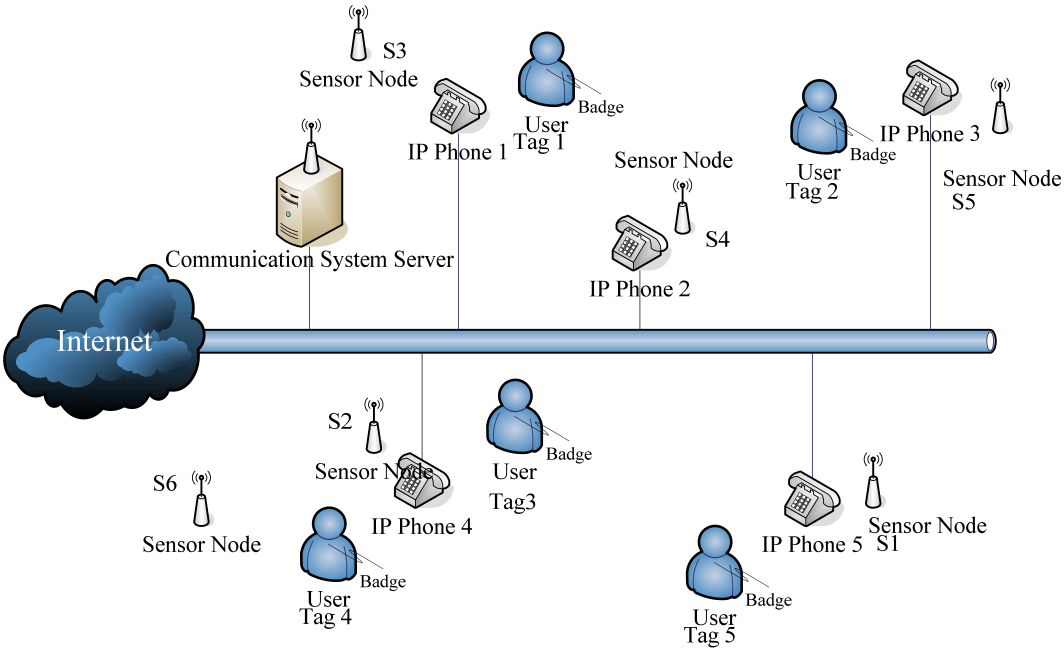

Fig. 5. The experimental environment

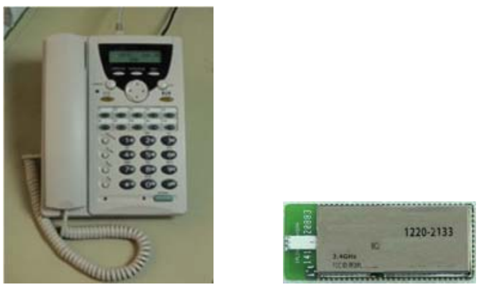

Fig. 6. LRPWAN device (right photo), a lighter size module, is used as a tag in user's pocket, or as a sensor node on IP phone (left photo).

Fig. 8 shows the software architecture of the IP-PBX system with Location Aware functionality. All software works in a Personal Computer with Linux OS. The major blocks: Agent, CM, LAM, and Node Manager are implemented in System Application layer. All sensor nodes' information is collected by a single LRPWAN device and then delivered to LAM via NM. Hence, NM has to handle the communication with the LRPWAN coordinator device via an interface which NM and the LRPWAN coordinator both support. The Agent hence uses system function to send shell command that SIP-PBX provides to perform an on-the-fly configuration and address updating.

In the initialization state, the content of the field “phone ID” in the “Extension Number” is equal to that of the field “Phone ID(formal)” of his/her owner and meanwhile, CM will configure SIP-PBX with this address mapping list. For example, an IP-Phone with phone ID “206” and a badge Tag #5 are assigned to the user M5 whose ID is “123456”. Any calls to number “123456” or “206” will be forwarded to Phone ID “206” when he/she is at his/her desk. If he leaves for a place near an IP phone whose phone ID is “201”, the CM will ask SIP-PBX to forward incoming calls for him/her to phone ID “201” instead. Fig.9 shows the messages from software. The first two lines in the of message indicate phone ID “206” is registered to user ID ”123456” while the last 3 lines represent that SIP-PBX performs the reassignment procedure to forward the calls to the phone with phone ID “201”.

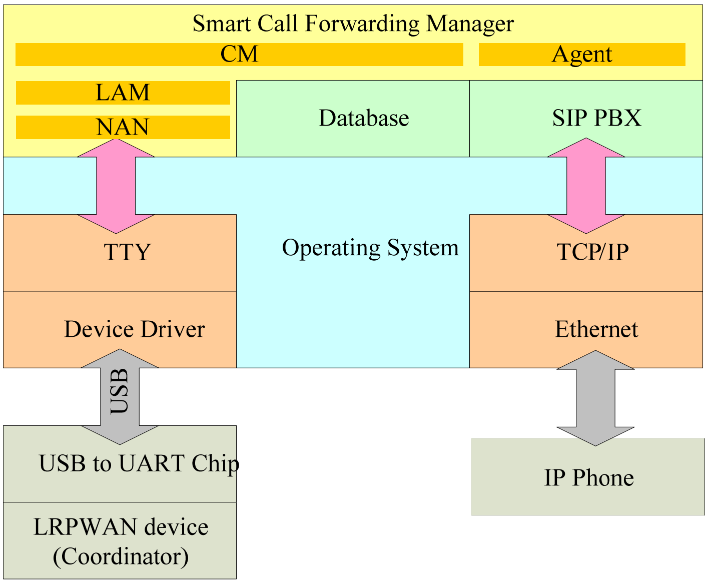

Fig. 7. Software Architecture of Host that consists of Smart Call Forwarding Manager software, and SIP PBX software, Database and Linux OS.

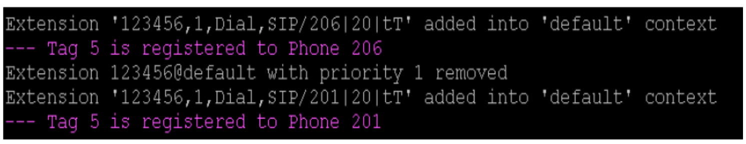
```
Extension '123456,1,Dial,SIP/206|20|tT' added into 'default' context
--- Tag 5 is registered to Phone 206
Extension 123456@default with priority 1 removed
Extension '123456,1,Dial,SIP/201|20|tT' added into 'default' context
--- Tag 5 is registered to Phone 201
```

Fig. 8. An example of phone automatic reassigning in our experiment system.

Fig. 10 shows the message composed of data from NM, LAM and CM to indicate the real-time status of mobile nodes in debug mode. The format of node's status is described in Fig. 11. In the message, the 3rd line illustrates that the mobile node 5 (tag #5) is absent from the User Aware Network because no sensor node can detect it and the last line describes that mobile node 5 is present again and detected by sensor node 1. Thus, LAM assigns a phone ID to the mobile node 5.

```
3->4 0x0004 0x7B 0xC0 0xC000  4 0 206
Extension 1234567@default with priority 1 removed
--- Removing tag #5...

1->4 0x0004 0x94 0xCD 0xC000  4 0 206
Sensor node #2 leaved the network.
3->4 0x0004 0x78 0xBE 0xC000  4 0 206

1->4 0x0004 0x81 0xC3 0xC000  4 0 206
Sensor node #2 leaved the network.
3->4 0x0004 0x9F 0xD2 0xC000  4 201 206

1->4 0x0004 0x5F 0xB0 0xC000  4 201 206
1->5 0x0005 0x6E 0xB8 0xC217  5 206 0
```

Fig. 9. The real-time status of mobile nodes.

Here we use the last line in Fig 10 for an example:

this part of Message below is from NM

1->5 : Tag 5 is detected by sensor node 1

----

this part of Message below is from LAM

0x0005: Tag 5 mobile node ID

0x6E : Link quality

0xB8 : Signal Strength

0xc217: Batter level of mobile node

----

this part of Message below is from CM

5 : Mobile ID

206 : Current area ID of mobile ID 5.

0 : Last area ID of mobile ID

Fig. 10. The format of message in Fig. 10.

V. CONCLUSION

VoIP [9] technique brings traditional PBX to a more powerful and flexible IP-PBX. Admittedly, to a company, the ideal improvement in a telephony system would be a major reduction in operation cost or even at no cost to achieve the same progress. But to a user, more powerful, friendly and even smarter functionalities should be most welcomed. In this paper, our proposed system would make any current telephony network become more intelligent in a smart space. Our system can also reduce unnecessary outgoing calls to PSTN or others, and provide a setting-free call forwarding service.

In our system, we consider not only the office space but also the users' and others' own space. Besides, we consider the heterogeneous node aware network and telephony device and its communication cost as well. For example, when a user is at home, CM will automatically ask PBX to forward all the calls to a SoftPhone [10], telephone instead of a mobile phone. If the user turns on a wireless IP phone in a public area that provides free wireless LAN service, the system should also find the phone requiring the lowest charge for making calls, and hence forward the calls to it accordingly.

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