ASSOCIATION MANAGEMENT BETWEEN EVERYDAY OBJECTS AND PERSONAL DEVICES FOR PASSENGERS IN URBAN AREAS

Hirobumi Shimizu[1], Osamu Hanzawa[1], Ken'ichiro Kanehana[1], Hiroki Saito[1], Niwat Thepvilojanapong[2], Kaoru Sezaki[2], Yoshito Tobe[1]

[1] Tokyo Denki University, Tokyo, Japan
[2] University of Tokyo, Tokyo, Japan
{hakubn, osamu, kei, hsaito, wat, yoshito}@unl.im.dendai.ac.jp, sezaki@iis.u-tokyo.ac.jp

Abstract

In many metropolitan areas, passengers of public transportations move between home and their destinations such as offices, schools, and entertainment places. Often, they use storing shelves/areas to temporarily place their personal belongings and they may leave them behind. We have developed CRUISE/r which is a prototype of lost and found systems utilizing multiple wireless devices and effectively notifying possible places of the lost thing. Our system accommodates the mobility of trains by using Mobile IPv6. We also introduce new notions: delegation and shared observation.

1 Passengers vs. Mobile Devices

Although some metropolitan areas such as Los Angeles in USA are highly dependent on automobiles, it is common that public transportations such as buses, subways, and railroads play a key role in conveying people in urban areas. People in such areas move between home and their destinations such as their offices and entertainment places using the public transportation. They may change trains or buses several times until they reach their final destination, and thus their personal belongings may be left behind in the place they are temporarily put onto.

Recent advancement of wireless technologies ranges from wireless telecommunications, wireless LANs, to RFIDs. We will see mobile phones equipped with an RFID reader and/or IEEE 802.11b. At the network layer, Mobile IPv6 [3] is effective in accommodating the mobility of the trains or buses. Therefore, lost and found systems utilizing a combination of these wireless technologies can be realized.

We developed a simple prototype system of such lost and found systems, called CRUISE/r. CRUISE/r characterizes itself as a system of using other people's cooperation. In the original CRUISE/r, the relationship between a person and his/her personal belongings cannot be disconnected. We have enhanced CRUISE/r to accommodate more flexible to temporary disconnection by introducing the notion of delegation and family observation. In this demonstration, we show the prototype of CRUISE/r for several scenarios.

2 Terminology

To clarify the relationship between devices, we use the terms shown in Table 1.

Table 1 Terminology for CRUISE/r

Personal Objects (POBs)	Personal belongings held by a passenger tagged with an ID
Personal Pobs Assisting Devices (PPADs)	Devices that passengers always carry. A PPAD is equipped with an RFID reader and an IEEE 802.11b interface.
Object Information Managers (OIMs)	Management stations that are connected to the backbone network and communicate with PPADs.
m-OIMs	OIMs inside vehicles. Their IDs need to be mobility transparent.
OIM cells	Communication areas that each OIM can cover.
Ppad Communication Range (PPCR)	Communication areas that each PPAD detects POBs.

This model can include a case in which a place of left personal belongings is mobile by introducing m-OIMs. M-OIMs are also equipped with functionalities of RFID readers, thereby directly detecting the existence of POBs. In general, OIMs do not need to be deployed only for supporting the mechanism of CRUISE/r; rather, other equipments for information services such as Smart Furniture [4] can be used as an OIM.

2.1 Three-Layer Communications

OIMs, PPADs, and POBs constitute a three-layer hierarchy of communications as shown in Figure 1. OIMs are assigned IPv6 addresses and form a backbone with each other. Since m-OIMs move between IP domains, Mobile IPv6 needs to be implemented in the whole OIMs and an Home Agent (HA) of m-OIMs for one train is located in a fixed IPv6 domain. PPADs communicate with their nearby OIMs via IEEE 802.11b and with POBs using RFID functions.

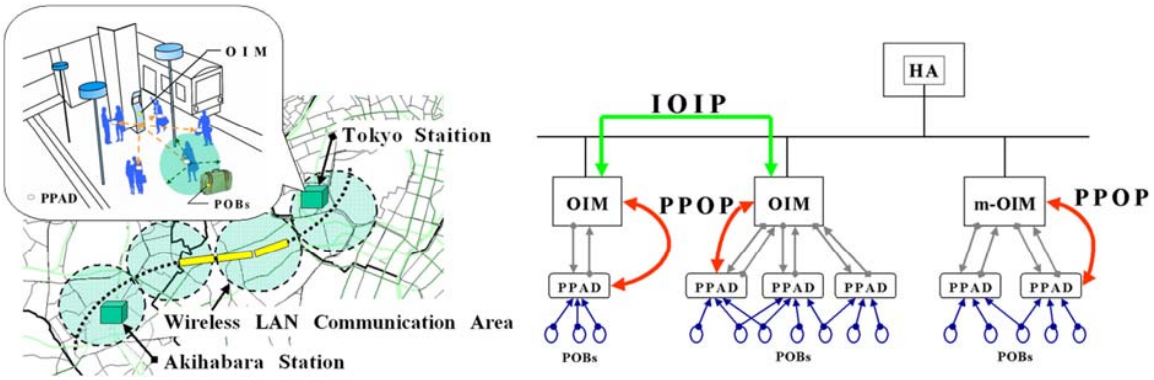

Figure 1 Three-layer hierarchy of communications

2.2 Delegation

A person inside a vehicle put his/her personal belongings onto a shelf or a storing area and temporarily leaves for a distant place. In the original CRUISE/r, this meant that a POB was disconnected from its managing PPAD; and after some expiration time, the POB was considered to be lost. To cope with this situation, we introduce delegation, in which management of the POB is transferred to the m-OIM. During the delegation period, the PPAD is notified of the sanity of the POB by the delegated m-OIM as long as the PPAD is within the PPCR of the m-OIM.

2.3 Shared Observation

In some cases, not only a single person but a group of people such as a family will hold their belongings when they travel together. This can be dealt with having a shared association between multiple PPADs and a POB. If an association is shared, the PPADs relevant to the association need to periodically communicate with each other to ensure the POB is under control.

2.4 Narrowing Search Areas

Flooding is a well-known method to detect an intended target node. However, flooding can be used when the ID of the target is containing information about routing as well as globally unique in the network. In CRUISE/r, flooding cannot be used because IDs of POBs are uniquely assigned but do not have routing capability. Instead, CRUISE/r uses the knowledge about the possibilities that the target exists by storing the history of locations a PPAD has passed by.

In addition to use of information in the past, CRUISE/r introduces prediction of possible danger of loss. Assuming that e-tickets than can be downloaded to PPADs are available, a path to the final destination is analyzed and OIM IDs on the path is stored into a PPAD. When a PPAD detects an OIM whose ID is identical to one of the stored OIM IDs, the PPAD notifies its user of the danger with an alarm signal.

3 CRUISE/r Protocols

We define a protocol called Ad hoc POB Discovery Protocol (APDP). APDP discovers the location of a POB by relaying discovery requests through OIMs and PPADs. The main feature in APDP is utilization of other people's PPADs since OIMs themselves cannot detect POBs. APDP is further divided into two protocols: PPAD-OIM Protocol (PPOP) and Inter-OIM Protocol (IOIP). A POB is searched using the combination of these two protocols. By separating the PPOP from the IOIP, PPADs are free from installing Mobile IPv6.

3.1 Searching

OIMs use IEEE 802.11b to communicate with PPADs within their cell. To record the route of journey, a PPAD periodically obtains IPv6 addresses of OIMs. Based on the route record, when the PPAD detects that a POB becomes a lost state, it sends PPOP-SEARCH request with the route record and the ID of the lost POB to a nearby OIM. Upon receiving the request, the OIM sends IOIP-SEARCH request to the OIM which is listed at the top in the route record.

The destination OIM of the IOIP-SEARCH request broadcasts PPOP-DISCOVER request with the target POB ID within its cell assuming that several PPADs exist in the cell. A PPAD that has

received the message initiates search for the requested ID using RFID communication. If the ID is detected, the PPAD sends a PPOP-DISCOVER response message to the OIM, which sends back IOIP-SEARCH response to the OIM which has initiated the IOIP-SEARCH request. Since some OIMs might not have been recorded into the PPAD, the POB may exist in a cell of another OIM near the destination OIM. Therefore, if the destination OIM does not receive a PPOP-DISCOVER response within an expiration time, it forwards the IOIP-SEARCH request to nearby OIMs by limiting time-to-live (TTL) of hopping. The destination OIM may be an m-OIM. This mechanism can also work for m-OIMs because all OIMs are Mobile IPv6 capable and thus an IOIP-SEARCH message is forwarded to an appropriate m-OIM utilizing Mobile IPv6 functions.

4 Related Works and Discussion

Smart-Its[2] exploits an explicit interaction for grouping devices. Smart-Its devices integrate sensing, processing, and wireless communication for connecting smart artifacts. In the concept of Smart-Its friends, multiple devices that are shaken together and have the same acceleration pattern, they are considered to belong to the same group. This concept can be extended to implicit grouping of devices [1]. When multiple everyday objects experience the same acceleration pattern, then these objects are treated as members of the same group. Although CRUISE/r does not provide this type of grouping, devices can transfer the association to each other. As a routing protocol used for sending packets to a destination without its identified location, epidemic routing [5] was proposed. This protocol utilizes users' mobility to deliver messages. In contrast to epidemic routing, routing used in CRUISE/r can limit the broadcasting area based on the history of the location of PPAD.

An obvious drawback of this scheme is the reliance on the cooperation by other people. Therefore actions can be probabilistic and there is no guarantee that a lost personal object is successfully detected. To solve this problem, giving incentive to the participants of CRUISE/r should be considered. As another problem, data tampering has not been included in the current CRUISE design.

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