International Journal of Informatics Society

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Informatics Society

Aims and Scope

The purpose of this journal is to provide an open forum to publish high quality research papers in the areas of informatics and related fields to promote the exchange of research ideas, experiences and results.

Informatics is the systematic study of Information and the application of research methods to study Information systems and services. It deals primarily with human aspects of information, such as its quality and value as a resource. Informatics also referred to as Information science, studies the structure, algorithms, behavior, and interactions of natural and artificial systems that store, process, access and communicate information. It also develops its own conceptual and theoretical foundations and utilizes foundations developed in other fields. The advent of computers, its ubiquity and ease to use has led to the study of informatics that has computational, cognitive and social aspects, including study of the social impact of information technologies.

The characteristic of informatics' context is amalgamation of technologies. For creating an informatics product, it is necessary to integrate many technologies, such as mathematics, linguistics, engineering and other emerging new fields.

Guest Editor's Message

Yoshimi Teshigawara
Guest Editor of the Fourth Issue of International Journal of Informatics Society

We are delighted to have the fourth and special issue of the International Journal of Informatics Society (IJIS) published. This issue includes selected papers from the Third International Workshop on Informatics (IWIN2009), which was held in Honolulu, Hawaii, USA, Sep 11-17, 2009. The workshop was held at Hawaii Tokai International College (HTIC). This workshop was the third event for the Informatics Society, and was intended to bring together researchers and practitioners to share and exchange their experiences, discuss challenges and present original ideas in all aspects of informatics and computer networks. In the workshop, 27 papers were presented at 4 technical sessions. The workshop was complete in success. It highlighted the latest research results in the areas of networking, business systems, education systems, design methodology, groupware and social systems.

Each IWIN2009 paper was reviewed in terms of technical content and scientific rigor, novelty, originality and quality of presentation by at two reviewers. From those reviews, 14 papers are selected for publication candidates of IJIS Journal. Among those 14 papers, 3 papers are related to computer networks. This fourth issue focuses on computer networks, and includes those selected 3 papers. The selected papers have been reviewed from their original IWIN papers and accepted as publication of IJIS. The papers were improved based on reviewers' comments. The rest of 11 papers will be reviewed for publication candidates as the fifth issue of IJIS Journal.

We hope that the issue would be of interest to many researchers as well as engineers and practitioners in this area.

We publish the journal in print as well as in an electronic form over the Internet. This way, the paper will be available on a global basis.

Yoshimi Teshigawara is a Professor of Department of Information Systems Science, Faculty of Engineering at Soka University since 1995, He began his professional career in 1970 at NEC Corporation, engaged in the design and development of computer networks. From 1974 to 1976, Dr. Teshigawara was a Visiting Research Affiliate with ALOHA System at the University of Hawaii where he did research on packet radio and satellite networks. He engaged in the design and development of computer systems via satellite using VSAT. His current interests are e-learning, ubiquitous computing, and network security. Dr. Teshigawara received his PhD from Tokyo Institute of Technology, Japan, in 1970.

Dr. Abramson's Speech in IWIN2009

Jun Munemori

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munemori@sys.wakayama-u.ac.jp

Amount of information is significantly increasing and various types of information are existed. IWIN is the International Workshop on Informatics. The workshop brings together researchers and practitioners to share and exchange their experiences, discuss challenges and present original ideas in all aspects of informatics. The workshop topics includes various ranges of informatics such as computer supported cooperative work, groupware, distributed computing, Information systems, mobile

Figure 1: Hawaii Tokai International College.

computing and computer networks. IWIN is the annual conference from 2007 and previous IWIN conferences successfully held. IWIN2009 was held at Hawaii Tokai International College (HTIC) in Honolulu, USA as shown in Figure 1. IWIN2009 arranged Dr. Norman Abramson's speech. Dr. Abramson is developer of ALOHA system and his technical contribution has significant impact on today's computer networks. IWIN2009 committees successfully invited him to share the original history of ALOHA system development with conference attendees.

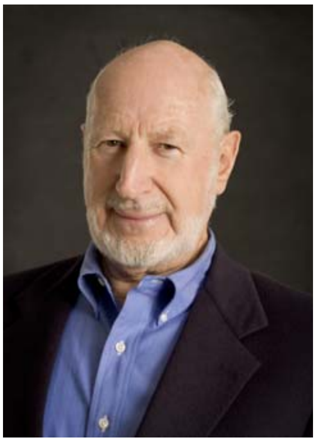

Figure 2: Norman Abramson.

The photograph of Dr. Abramson is presented as Figure 2. Dr. Abramson is director of the ALOHA System at the University of Hawaii. He developed and operated the ALOHANet, which has been called the

Figure 3: Dr. Abramson in invited speech.

first modern data network. The ALOHA System utilized UHF to provide a terrestrial data network (ALOHANet) within the state of Hawaii in 1971. In 1973 the ALOHA System used VHF and an experimental NASA satellite (ATS-1) to establish an international satellite data network (PacNet) connecting NASA in California and five universities in the USA, Japan and Australia. Also in 1973, the ALOHA System pioneered the unconventional use of a conventional Comsat channel to link these two early networks to ARPANet in the continental US.

The biography of Dr. Abramson is as follows. He was Assistant Professor and Associate Professor of Electrical Engineering, Stanford University, 1958-1965. He was Visiting Professor, Berkeley, Harvard and MIT (1965, 1966, 1980). He was Professor of Electrical Engineering,

Figure 4: Dr. Abramson and conference attendees.

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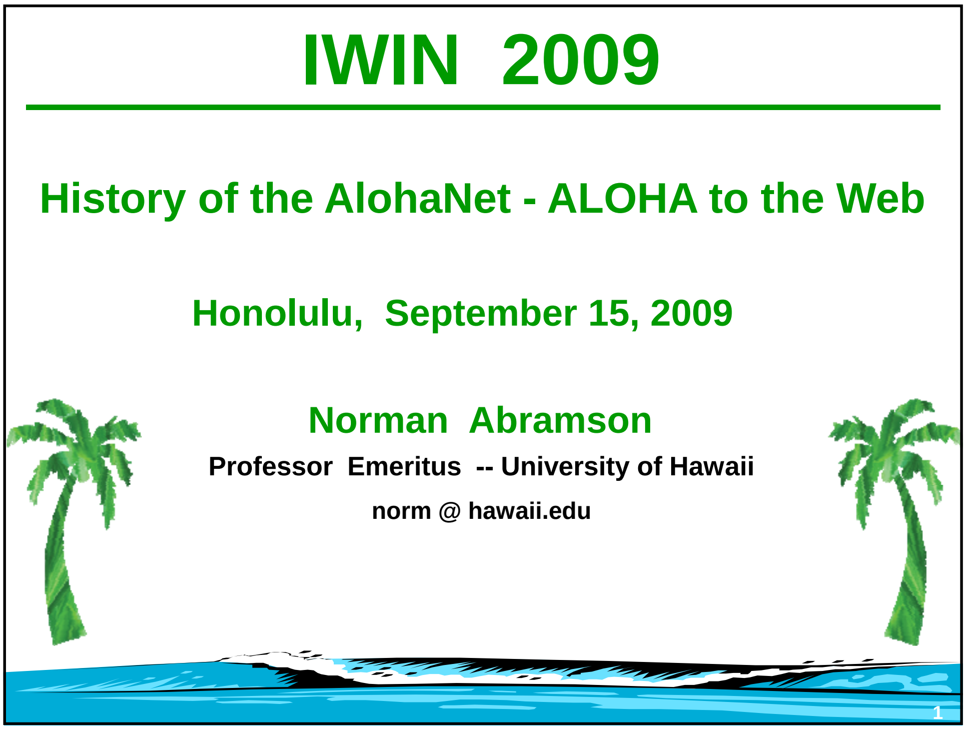
Professor of Information and Computer Science, First Chairman, Department of Information and Computer Science, University of Hawaii (1966-1995). He is Professor Emeritus, University of Hawaii (2005 -).

Dr. Abramson's speech was slotted as 60 minutes presentation in IWIN2009. He gave us a talk on "History of the Alohanet – ALOHA to the Web". The snapshots of his invited speech are presented as Figure 3 and 4. I'm pleased to note that his interesting and informative presentation slides are included in this issue of IJIS.

(Received April 14, 2010)

Jun Munemori received the B.E. and M.E. degrees in electrical engineering from Nagoya Institute of Technology, Nagoya, Japan, the D.E. degree in electrical and electrical communication engineering from Tohoku University, Sendai, Japan, in 1979, 1981, and 1984, respectively. He worked in Mitsubishi Electric Corp., Kagoshima University, and Osaka University. He is currently a professor of Department of Design and Information Sciences at Wakayama University. His interests are groupware, human interface, and neurophysiology. He received IPSJ SIG Research Award, IPSJ Best Paper Award, IEEE CE Japan Chapter Young Paper Award, and KES2005 Best paper award, in 1997, 1998 2002, and 2005, respectively. He is a member of ACM, IEEE, IPSJ and IEICE.


IWIN 2009
History of the AlohaNet - ALOHA to the Web
Honolulu, September 15, 2009
Norman Abramson
Professor Emeritus -- University of Hawaii
norm @ hawaii.edu
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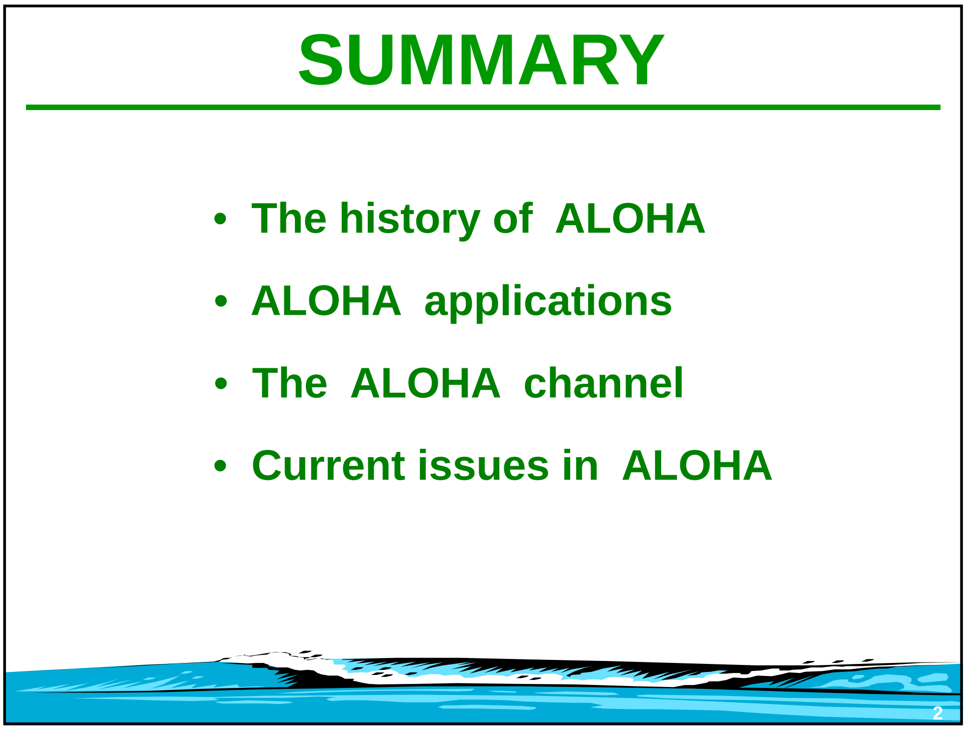
SUMMARY
• The history of ALOHA
• ALOHA applications
• The ALOHA channel
• Current issues in ALOHA
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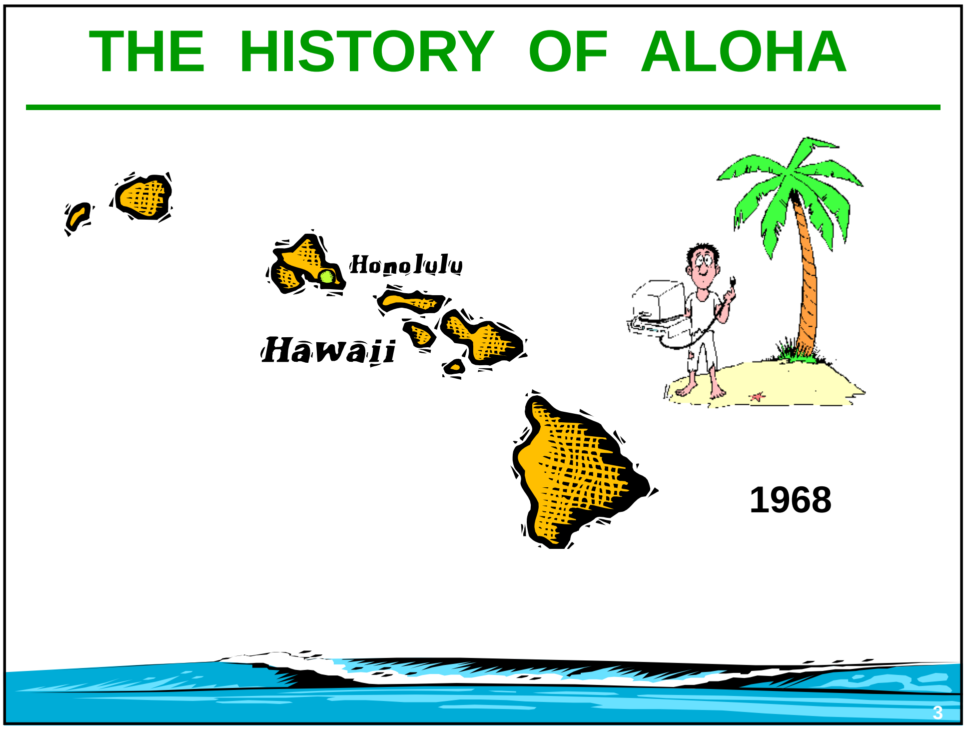
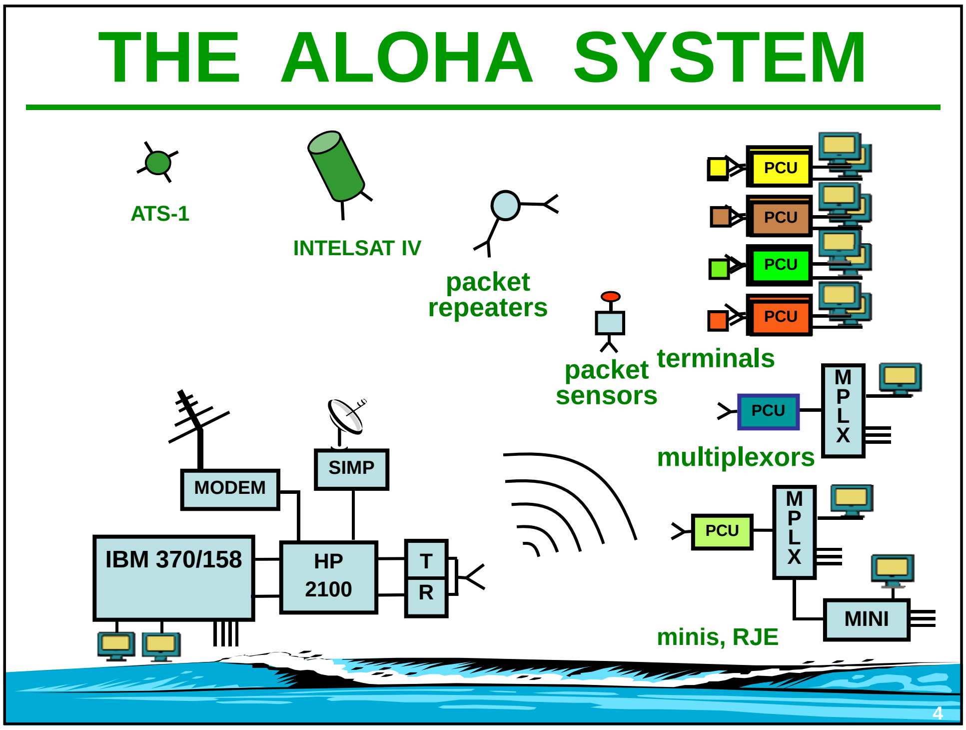
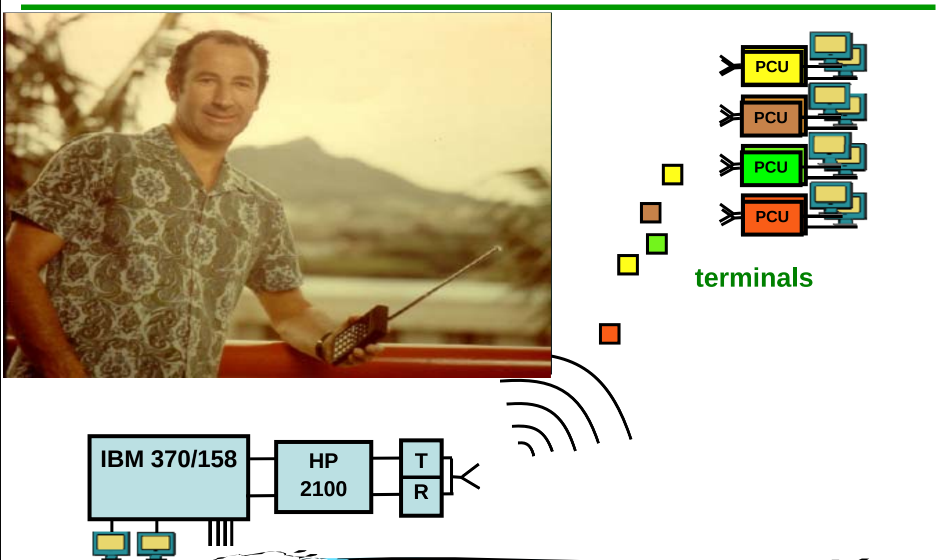

THE HISTORY OF ALOHA
Honolulu
Hawaii
1968
3


THE ALOHA SYSTEM
ATS-1
INTELSAT IV
packet
repeaters
PCU
PCU
PCU
PCU
packet
sensors
terminals
PCU
M
P
L
X
multiplexors
MODEM
SIMP
IBM 370/158
HP
2100
T
R
PCU
M
P
L
X
MINI
minis, RJE
4

THE ALOHANET



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SUMMARY

- The history of ALOHA
- ALOHA applications
- The ALOHA channel
- Current issues in ALOHA

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ALOHA APPLICATIONS

1. wired and fixed wireless (LANs)
2. satellite networks
3. wireless mobile networks

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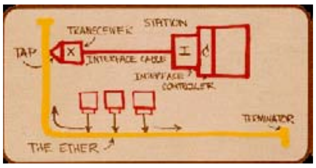
LANs – ETHERNET

- Alto ALOHA Network – Metcalfe ‘73
- CSMA/CD – Kleinrock / Tobagi ‘75
- Standard – IEEE 802.3 ‘83 ……



1973

2009

8

LANs – WiFi

- unlicensed bands (US) ‘85
- CSMA/CA – Kleinrock / Tobagi ‘75
- standard – IEEE 802.11 ‘97 ……

1995

EtherNet or ALOHANet ?

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LANs – WiFi (Applications)

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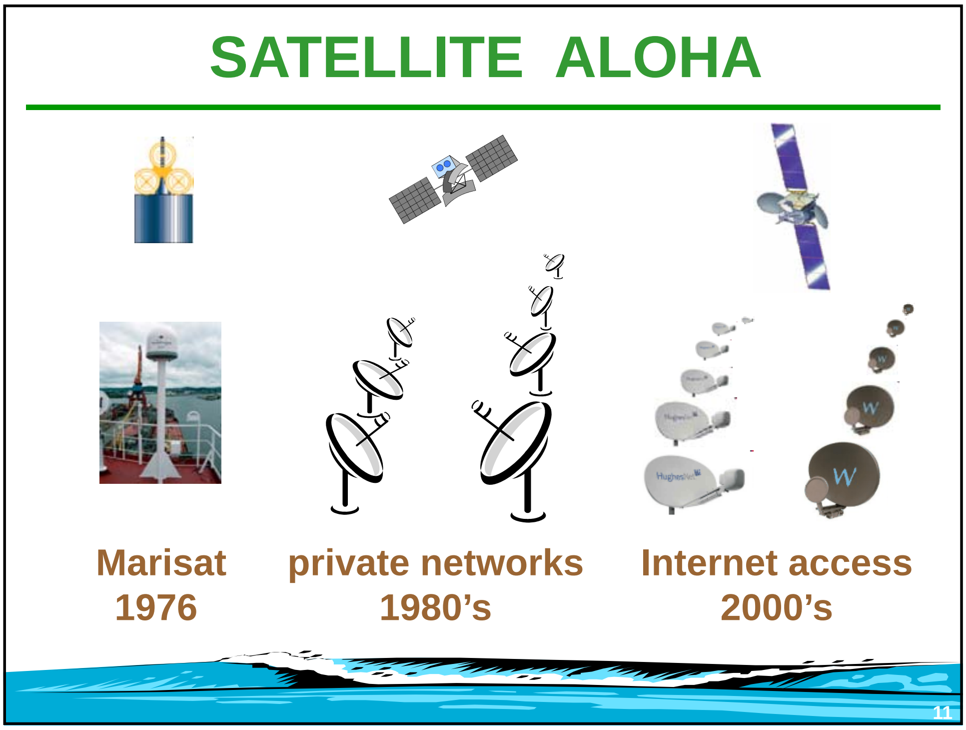
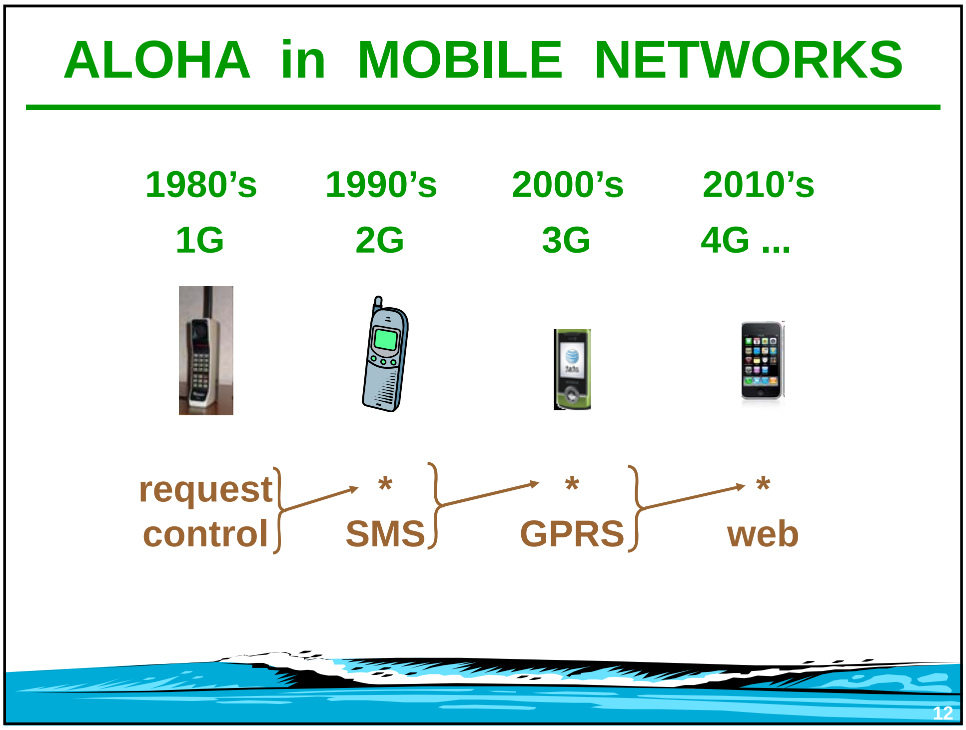

SATELLITE ALOHA
Marisat
1976
private networks
1980’s
Internet access
2000’s
11


ALOHA in MOBILE NETWORKS
1980’s
1G
1990’s
2G
2000’s
3G
2010’s
4G ...
request
control
*
SMS
*
GPRS
*
web
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SUMMARY

- The history of ALOHA
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- The ALOHA channel
- Current issues in ALOHA

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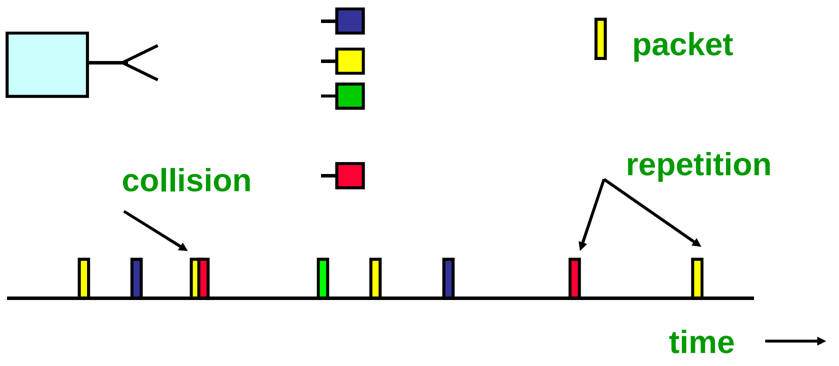
THE ALOHA CHANNEL



maximum throughput $= \dfrac{1}{2e} = 0.186$

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ALOHA FLAVORS

- unslotted ALOHA
- slotted ALOHA
- reservation ALOHA
- CSMA
- spread ALOHA

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SUMMARY

- The history of ALOHA
- ALOHA applications
- The ALOHA channel
- Current issues in ALOHA

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CURRENT ISSUES in ALOHA

- to slot or not to slot ?
- spread ALOHA – CDMA w/o CD
- WiFi – EtherNet or ALOHANet ?
- bursty traffic – charging by the byte
- throughput and protocol overhead

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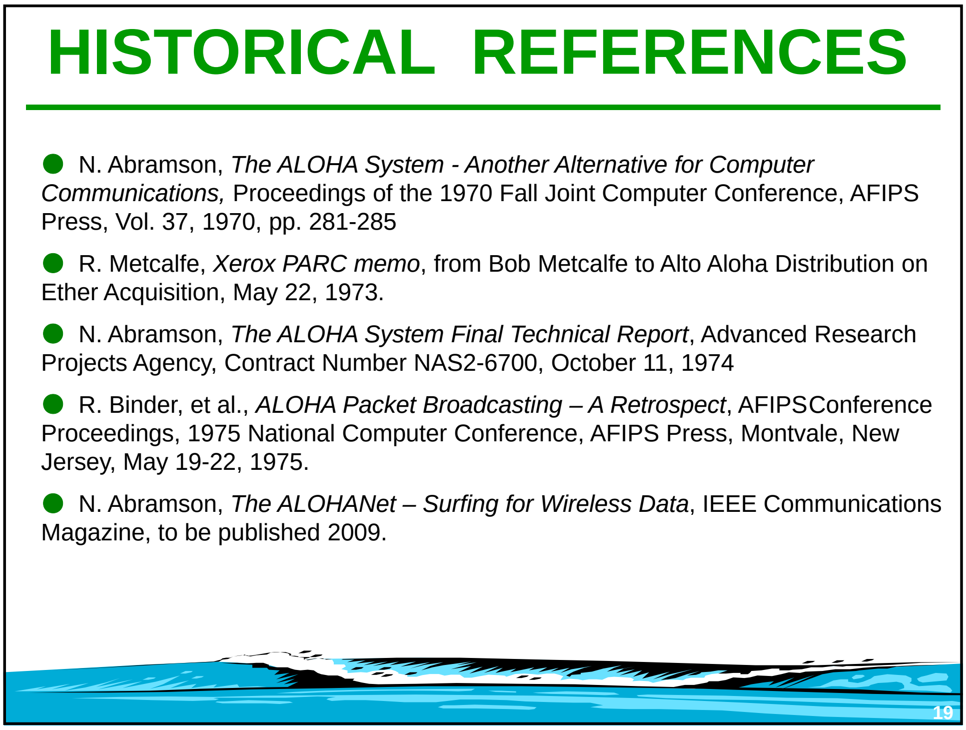
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N. Abramson, The ALOHANet – Surfing for Wireless Data, IEEE Communications Magazine, to be published 2009.
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Proposal and Implementation of Coordinate Integrations in Heterogeneous Network Protocols

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Abstract - Location estimation is important for ad-hoc and sensor networks. Existing localization techniques assume to be operated in a single network protocols. We propose coordinate integrations for heterogeneous network protocols. The fundamental concept of coordinate integrations is where a set of coordinates is iteratively integrated by using at least three shared nodes in two-dimensional space, so that coordinates generated in different network protocols become compatible across the networks. We used simulation to demonstrate the proposed coordinate integration. We also present details of implementations on sensor nodes and experimental results for RSSI measurements inside a university building.

Keywords: Localization, location estimation, sensor networks, heterogeneous networks, ad-hoc networking

1 Introduction

Ad-hoc networking enables a wireless network to be constructed without an infrastructure network such as a base station. Ad-hoc networking also enables nodes to relay a data using multi-hopping. Emerging products of sensor networks such as Zigbee use ad-hoc networking capabilities over IEEE 802.15.4 [6]. Other wireless networking technologies such as wireless local area Networks (WLANs) and bluetooth support ad-hoc networking over IEEE 802.11 [4] and 802.15.1 [5].

Localization is an attractive functionality of using ad-hoc networking capabilities, which enables nodes to estimate their positions. The motivation for developing a localization technique is to inform an observer of the many deployed node positions with a small number of anchor nodes whose positions are known in advance. Location information is not only used for bundling sensing events with their locations, but also for improving network performance.

Anchor-free localization was proposed in [11], and it has received much attention. The advantage of the anchor-free localization is that it enables nodes to estimate their positions without using anchor nodes. The set of node coordinates is relatively determined, and hence it assigns an arbitrary relative coordinate system in each network protocol.

Assume that the nodes are deployed over a field and that they have incompatible network protocol. When anchor-free localizations are applied to heterogeneous network protocols that have different network protocols coexisting, one coordinate system is incompatible with other coordinate systems. This is because the set of node coordinates is relatively determined. Therefore, nodes cannot use location information obtained using anchor-free localizations across other network protocols.

In this paper, we propose coordinate integrations for heterogeneous network protocols. Sets of estimated coordinates in heterogeneous network protocols are iteratively integrated using nodes that physically share same coordinates on different network protocols. The coordinates are then compatible for heterogeneous network protocols. We first conducted simulation evaluation to verify the proposed coordinate integration. We are currently implementing functionalities of proposed coordinate integration on sensor nodes, and present details of the implementation.

This paper is organized as follows. Related work and localization issue in heterogeneous network protocols are described in Section 2. Proposed coordinate integration is presented in Section 3. An evaluation of coordinate integration using simulation is presented in Section 4. A detail of our implementations of coordinate integration is presented in Section 5. Results for RSSI experiments are reported in Section 6. Section 7 concludes the paper and mentions future work.

2 Related work and issue

2.1 Related work

Localization techniques have been discussed for wireless multi-hop networks such as sensor and ad-hoc networks. The motivation behind developing multi-hop localization is required to know the node position in wireless multi-hop networks by using a small fraction of the anchor nodes. An anchor node is one whose position is known in advance through means such as global positioning system (GPS). A simple solution to obtaining location information is to equip each node with a GPS receiver. However, a GPS receiver cannot always receive signals from GPS satellites when it is located in a building, and it enforces equipment costs for nodes. Much research has been conducted on how to estimate node positions in wireless multi-hop networks. Most localization techniques can be categorized into two types. The first is localization by using extra ranging devices, such as ultra sound devices, and the second is localization without using extra ranging devices.

AHLoS [10] is the distance-measurement localization approach using ultra-sound ranging devices. In AHLoS, at least three anchor nodes iteratively conduct multilateration to es-

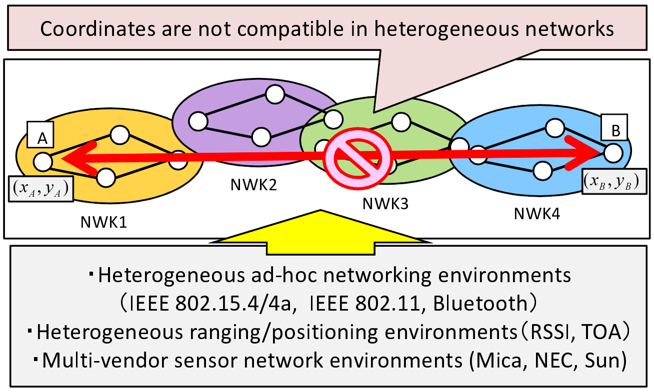


Figure 1: Localization issue in heterogeneous network environments.

timate unknown node positions. Once the positions for unknown nodes are estimated by anchor nodes, the nodes are configured as pseudo-anchor nodes and estimate unknown nodes that remain in the network. In sweeps [14], algorithms to identify global rigidity were employed to estimate the node positions without flipping for sparse node networks. The distance-measurement approach normally achieves precise positioning accuracy. However it requires extra ranging devices, increasing the cost for all nodes.

The localization scheme without using extra ranging devices has been developed for large-scale sensor networks, and it exploits connectivity information of multi-hop networks. In DV-Hop [9], the positions for unknown nodes in a network are estimated by using trilateration using average hop-count distances from at least three anchor nodes. In anchor-free localization (AFL) [11], the positions of unknown nodes are estimated without using anchor nodes. The basic idea behind AFL is to select reference nodes that represents the relative axis in a network and they determine relative node positions based on the hop-counts from their reference positions..

Some research proposed to use multidimensional scaling (MDS) [12, 15] to estimate node positions. MDS is the statistical technique to obtain geographical representations of data from data proximity. Since distance information can be used as data proximity, MDS can plot the relative coordinates of nodes in a network. Basic idea to apply MDS to localization technique is that node collects distance information such as hop-count and TOA measurement and calculates relative node positions by using MDS.

The localization scheme without using ranging devices enables nodes to estimate node positions while only using the radio capabilities of a sensor node. Hence, it has great flexibility to enable nodes to be applied to localization in the network. However, existing localization techniques are assumed to be operated in single network protocols.

2.2 Localization issue in heterogeneous network environments

Figure 1 presents a localization issue in heterogeneous network environments. Some localization techniques require an-

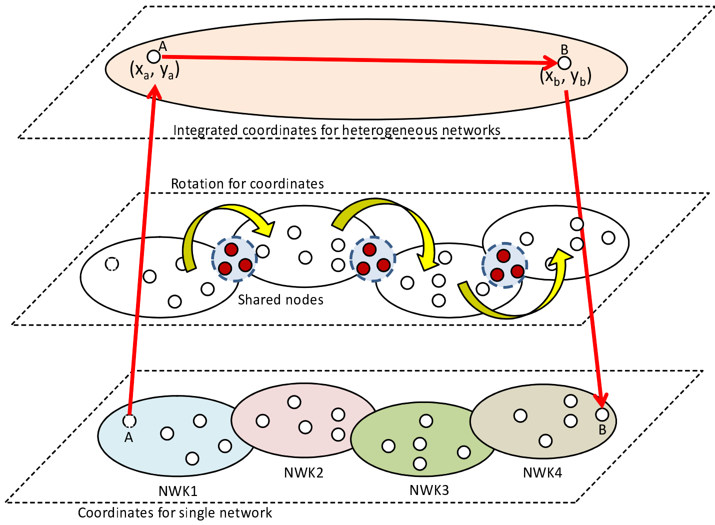


Figure 2: Conceptual illustration of proposed coordinate integrations.

chor nodes that have the unique original point of the coordinate system. For example, GPS has the original point that is centroid of earth in the coordinate system. The coordinate system has the original points in its own network, however these coordinate system can be arbitrary determined in the network. In addition, in anchor-free localization, the estimated coordinates are relatively determined and original points are arbitrary determined. Therefore, coordinate systems that are generated by using localization techniques in different network protocols are not compatible with each other. Especially, localization technique using ad-hoc networking capability can be more general technique for position estimations since anchor-free localization only requires ad-hoc networking capability to estimate node positions. Currently, several IEEE standardized networking protocols such as IEEE 802.11 [4], IEEE 802.15.4 [6], IEEE 802.15.1 [5] (bluetooth) supports ad-hoc networking capability. However these networking protocols are not able to communicate with different network protocols. In the sensor networks, networking protocols such as Zigbee [1] have been standardized. Several vendors such as MICA and NEC have released sensor nodes in market. However, one vendor's sensor node cannot communicate with another vendor's sensor node. In heterogeneous network protocol environments, we encounter an issue that one set of coordinates generated by a network cannot be used in another network as shown in Fig. 1. Hence, a mechanism that converts coordinates generated in heterogeneous network into one set of coordinates that is compatible across the networks is required.

3 Coordinate integrations for heterogeneous network protocols

3.1 Overview

Figure 2 shows a conceptual illustration of proposed coordinate integrations. We consider that heterogeneous network

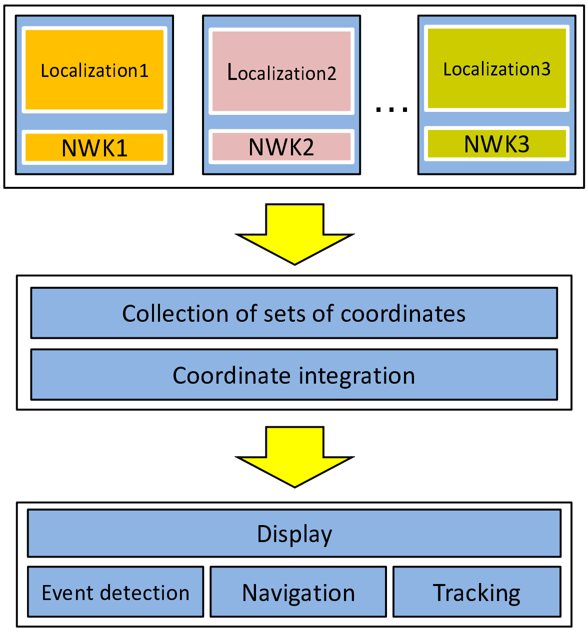


Figure 3: Logical organization for proposed coordinate integration.

protocols are coexisted in a field as shown in bottom of Fig. 2. Each network protocol conducts localization techniques by using ad-hoc networking capability. In the coordinate integration, coordinates estimated by each localization protocols are integrated by using at least three shared nodes as shown in middle of Fig. 2. The shared node is the node that physically shares same coordinates in different network protocols. Some nodes in different network protocols are set as shared nodes for the coordinate integration. The integrated coordinates are compatible with different network protocols and they can be accessed by users as shown in top of Fig. 2.

Coordinate integrations for heterogeneous network protocols are conducted as follows.

1. **Coordinate assignments:** Each node in the heterogeneous network protocols estimates its relative or absolute node coordinates within its network protocol. Developing the precise localization algorithm is not our focus for this paper. Reader may refer to the literature [11].

2. **Coordinate conversions:** The orientations of two sets of coordinates are adjusted into one set of coordinates by using three or more shared nodes. The coordinate conversion requires rotation, flipping and translation operations. Here, we used procrustes analysis [17] for the coordinate conversions.

3. **Coordinate integrations:** Two sets of coordinates in different network protocols are integrated into one set of coordinates. The other sets of coordinates are iteratively converted and integrated into one set of coordinates. The coordinate system is then compatible for heterogeneous network protocols.

Figure 3 presents the logical organization of proposed coordinate integration. When nodes in heterogeneous network conduct a localization technique, one set of coordinates of network that is incompatible is generated (top of Fig. 3). One localization server collects all sets of coordinates of networks, and conduct coordinate integration to be compatible with each other (middle of Fig. 3). The coordinates that is compatible with heterogeneous network protocols are available for application such as event detection, tracking and navigation regardless of the network protocols (bottom of Fig. 3).

3.2 Algorithm

The objective of proposed coordinate integration is to convert sets of coordinates that are incompatible with other coordinates of networks into a set of coordinates that is compatible with other coordinates of networks. Therefore, localization technique to obtain estimated coordinates is not our main focus of the proposed coordinate integration. In this work, we assumed to use MDS that can obtain the relative coordinates of networks from distance measurements such as RSSI.

MDS [17] is statistical technique used to analyze proximity data in multidimensional space. The proximity data for MDS can be represented by geographical expression. Therefore proximity matrix that is constructed by using node distances can be transformed to the relative coordinate system by using MD.

MDS to obtain relative coordinates from node distance is operated as follows. First a node constructs the squared distance matrix,

$$\mathbf{D}^{(2)} = \{\hat{d}^2_{\{k,l\}}\}, \tag{1}$$

where the number of nodes is n and the node distance between (i, j) is denoted by d_{ij}. Multi-hop distances are approximated by using hop-couting. The scalar product matrix, $\mathbf{B}$ is constructed by applying double centering as

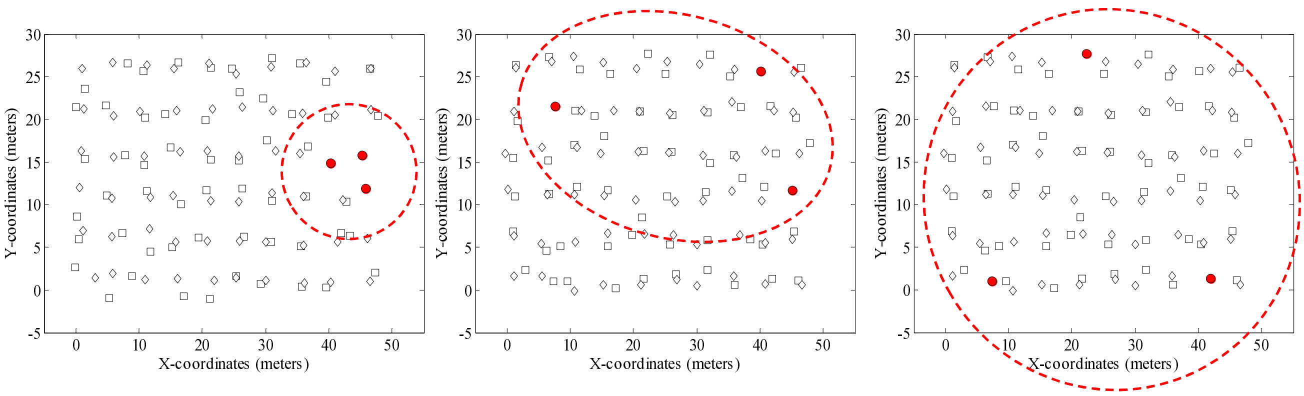
$$\mathbf{B} = -\frac{1}{2}\mathbf{J}\mathbf{D}^{(2)}\mathbf{J}, \tag{2}$$

where $\mathbf{J} = \mathbf{I}_n - \frac{1}{n}\underline{1}\underline{1}^T$ and $\underline{1}$ is an n by 1 vector of ones and n is the length of $\mathbf{D}_i$. A singular value decomposition is conducted as

$$\mathbf{B} = \mathbf{U}\mathbf{\Lambda}\mathbf{U}^T. \tag{3}$$

A coordinate matrix is then given by $\mathbf{X} = \mathbf{U}\mathbf{\Lambda}^{1/2}$. Node position $P_i^0(x_i^0, y_i^0)$ is obtained by extracting the first and second columns of $\mathbf{X}_i$.

When the coordinate system is relative such as MDS or the original points of coordinate systems are different, coordinate systems are not compatible with each other. In order to address this issue, we used procructes analysis [17] to rotate sets of coordinates. Procrustes analysis for coordinate rotation is operated as follows. Consider that two sets of coordinates X, Y that are not compatible with each other. Each set of coordinates is represented by matrix. Two sets of coordinates assume to have at least three shared coordinates. Objective of rotation operation of coordinates is to derive rotation matrix $\mathbf{T}$. First two sets of coordinates are multiplied



(a) Min neighbor (b) Random (c) GDOP-based

Figure 4: Shared node placements for different selection methods. (a): Min neighbor method, (b): random method, (c): GDOP-based method. Nodes for two different network protocol represented by squares and diamonds are overlapped. Shaded circles indicate shared nodes.

as $\mathbf{A} = \mathbf{X}^T\mathbf{Y}$. We then calculate singular value decomposition for matrix $\mathbf{A}$ as $\mathbf{A} = \mathbf{LDM}^T$. The rotation matrix for coordinates is then derived as

$$\mathbf{T} = \mathbf{ML}^T. \quad (4)$$

The coordinates Y can be compatible with coordinates X by

$$\mathbf{Z} = \mathbf{T}^T\mathbf{Y} + c, \quad (5)$$

where c is translation component. Finally, in order to derive the coordinates $\mathbf{R}$ that is compatible with X, Y, two set of coordinates are integrated into one set of coordinates by averaging as

$$\mathbf{R} = \frac{1}{2} * (\mathbf{X} + \mathbf{Z}). \quad (6)$$

Sets of coordinates are repeatedly integrated for other coordinates of networks based on shared nodes.

3.3 Placement for shared nodes

3.3.1 Min neighbor method

In the coordinate integration, at least three shared nodes that have same coordinates for different networks are required. Here we discuss three methods on placements for shared nodes.

Figure 4 shows three patterns of node placements for shared nodes. In Fig. 4, nodes for two different network protocol represented by squares and diamonds are overlapped and co-existed in a field. Shaded circles indicate shared nodes.

One possible method for determining shared node placement is min neighbor. In min neighbor methods, one node is randomly selected and other two nodes that are closest to it are selected as shown in Fig. 4(a). The advantage of the method is that it can be easy to place the share nodes for heterogeneous network environments.

3.3.2 Random method

Random method is that nodes for shared coordinates are randomly selected as shown in as shown in Fig. 4(b). The random method suggests that user does not take care of location for share nodes.

3.3.3 GDOP-based method

GDOP-based method selects shared nodes based on the geometrical dilution of precision (GDOP) [8]. GDOP was used to indicate the geometric conditions of the anchor nodes (i.e., GPS satellites in GPS) defined as the following equation.

$$GDOP = \sqrt{\frac{N_A}{\sum_{i \in S_A} \sum_{j \in S_A, j>i} A_{ij}^2}}, \quad (7)$$
$$A_{ij} = \sin \theta_{ij}.$$

In Formula (7), N_A indicates the number of anchor nodes, and S_A is the set of anchor nodes, and A_{ij} is the angle from an unknown node to anchor nodes $\{i, j\}$. When GDOP is small value, condition for anchor node to estimate unknown node would be good. GDOP takes small value when the area of anchor nodes is larger as shown in Fig. 4(c). GDOP-based method selects three nodes that have minimum GDOP when all nodes are assumed to be anchor nodes.

4 Simulation

4.1 Simulation setting

We tested the coordinate integrations using a simulation. The objective of using the simulation is to demonstrate the coordinate integrations for heterogeneous network protocols before the implementation. Simulation tool we used was Matlab. We assumed to use the received signal strength (RSS) to measure the distance. The RSS measurement can be modeled

Table 1: Simulation parameters.

Parameter	Value
n_p	2.5
P_t	$-50.0 - -35$ (dBm)
σ^2_{dB}	5.0(dB)
Receiver sensitivity	-73.0 (dBm)

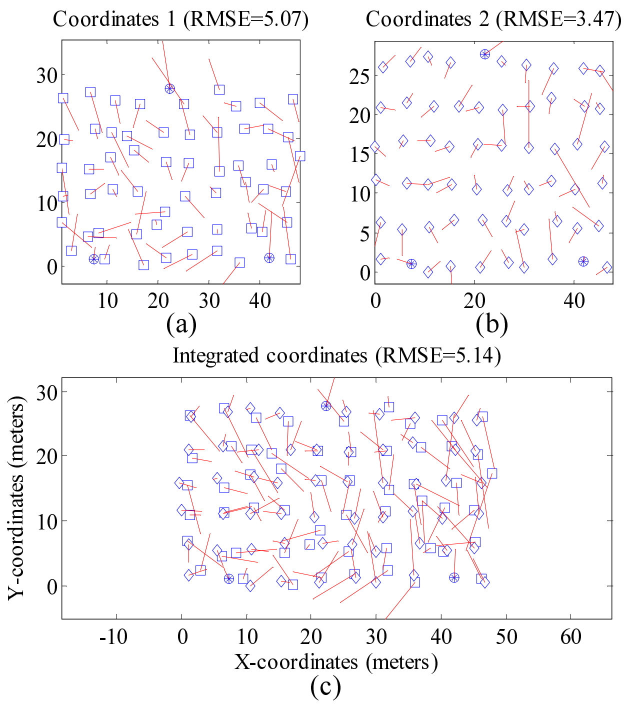


Figure 5: (a, b): relative coordinates systems for network 1 and 2. (c): relative coordinates system after coordinate integration. Actual node positions on network 1, 2 are represented by squares and diamonds, and their shared nodes are represented by asterisks. Errors are drawn by solid lines

as [16]

$$P_r = P_t - 10 n_p \log_{10}\left(\frac{d}{d_0}\right) + X_\sigma. \quad (8)$$

$\overline{P_0}$ (dBm) is the mean signal strength and P_t (dBm) is the received signal strength at reference distance d_0. X_σ is zero-mean Gaussian distribution with variance σ^2_{dB} for the lognormal shadowing, and n_p is path loss exponent determined in the measurement environment [16]. Table 1 shows the parameters used in the simulation. $n_p = 2.5$ and $\sigma^2_{dB} = 5$ were chosen in the simulation. Field size of node placement is 30 (height) $\times$ 50 (width) [m^2]. We assumed two vender sensor networks that are incompatible with each other are deployed in the filed. The number of nodes on each network was 60.

4.2 Results

Figures 5(a)(b) show each set of estimated positions using the MDS, and Fig. 5(c) shows the integrated coordinates of two networks. The shared nodes are selected by using GDOP-based methods. The two sets of estimated coordinates in different network protocols were successfully integrated into one set of coordinates based on coordinates of shared nodes by using procrustes analysis. We defined root mean square error (RMSE) as follows

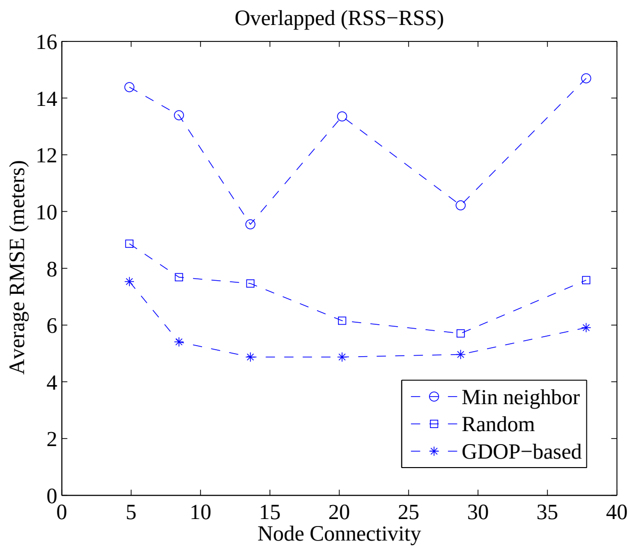


Figure 6: Average RMSE against node connectivity.

$$\textbf{RMSE} = \sqrt{\frac{1}{N}\sum_{i=1}^{N}\{(X_i - X_i^t)^2 + (Y_i - Y_i^t)^2\}}, \quad (9)$$

where $(X_i, Y_i), i = 1 \ldots N$ is estimated node position and (X_i^t, Y_i^t) is actual node position. RMSE of coordinates 1, 2 and integrated coordinates were 5.0, 3.4, and 5.1 (m), respectively.

Figure 6 shows average RMSE plotted with varying node connectivity. Node connectivity shows how many nodes connect to other nodes in 1-hop on average, and it is varied by increasing communication range, i.e., increasing P_t. As shown in Fig. 6, GDOP-based method achieved best performance of other methods. GDOP-based method selects the three shared nodes that have larger regular triangles. This avoids flipping that introduces the wrong orientation of integrating two coordinate. On the other hand, min neighbor method had poor performance. This is because the integrated coordinates of two networks includes flipping results. A flipping is introduced by an ambiguity of coordinate selection [11, 13]. Once a flipping is happened, estimated coordinates of the network yield a tremendous error. Therefore, RMSEs of min neighbor method were fluctuating.

Our simulation results only cover simple scenarios of integrating two coordinate systems. We are currently planning to conduct simulations with more complex scenarios including a mixed TOA/RSSI and different localization algorithms such as trilateration in large-scale heterogeneous networks. The detailed characteristics for coordinate integrations will be analyzed in the simulations.

Table 2: Basic specifications for Renesas and SunSPOT sensor nodes.

	Renesas node	SunSPOT
RF module	Freescale MC13202	TI CC2420
PHY/MAC	IEEE 802.15.4	IEEE 802.15.4
Frequency	2.405–2.48GHz	2.40–2.4835GHz
Receiver sensitivity	−92dBm	−95dBm

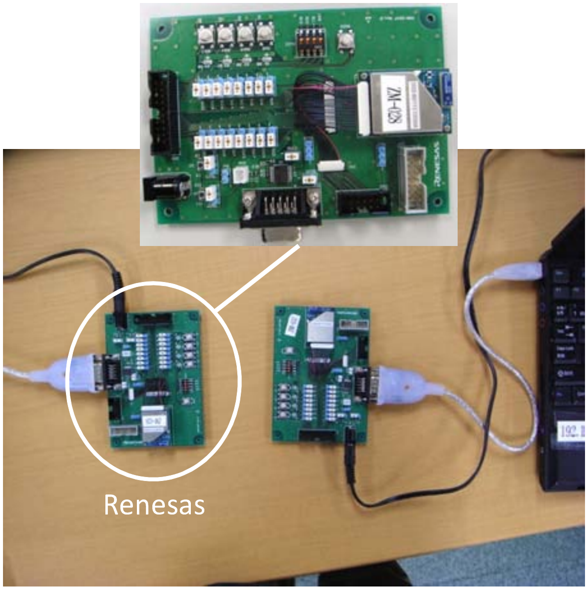


Figure 7: Snapshots of Renesas sensor nodes.

As shown in Fig. 6, GDOP-based method increased the RMSE when the node connectivity was over 20. One explanation for this result is that attenuation model of RSS used in Formula (8) gets slower and variances get larger when the communication range is longer. Hence, when the communication range is increased, RMSE gets wrong. The result suggests that nodes are required to vary communication range to achieve less RMSE.

We discuss potential applications of using location information provided by the localization technique in sensor networks. Supporting location information in sensor networks enables us to develop many kinds of location-based applications such as firefighter navigation and equipment monitoring [7]. Our target application of localization technique is a smart air conditioning system using sensor networks [18]. Existing air conditioning system only utilizes single sensor such as infra-red (IR) to measure temperature in a room and the sensing coverage is limited. The smart air conditioning system called "i-fan" uses sensor networks to measure temperature and the corresponding location by using localization techniques. Although it is future work whether i-fan satisfies the location accuracy provided by our localization system, we are aiming to develop such location-based application.

Figure 8: Snapshots of SunSPOT sensor nodes.

5 Implementation

We are currently implementing functionalities of the proposed coordinate integration by using actually released sensor nodes. We used a sensor node developed by Renesas [2] and SunSPOT developed by Sun Microsystems [3]. Table 2 shows the basic specifications for the sensor nodes.

Figure 7 shows the snapshots of Renesas sensor nodes. Renesas node has a main board with serial interface of RS-232C and equips with radio frequency (RF) modules. The RF module of Renesas node employs MC13202 developed by Freescale, and it uses IEEE 802.15.4 protocol for the PHY/MAC layers. The power is supplied by AC adapter. Renesas node provides a writable memory that a user can write the program. A user can control the microcomputer of Renesas node by writing the program. The RF module of Freescale has a functionality to store received signal strength indicator (RSSI) into registers on Renesas node. We implemented an output function of RSSI value by reading the registers of microcomputer on Renesas node.

Figure 8 shows the snapshots of SunSPOT. SunSPOT is the sensor node that can control the microcomputer by using Java program. SunSPOT has USB interface and the program can be written and debugged through the USB interface connecting to PC. SunSPOT can be operated by using battery on the board, and its power can be also supplied by using the USB cable. The RF module of SunSPOT employs CC2420 developed by Texas Instruments (TI), and it uses IEEE 802.15.4 protocol for the PHY/MAC layers. SunSPOT has $\mathbf{getRssi}()$ that is application programming interface (API) to extract the RSSI. We implemented an output function of RSSI by using the API.

Both Renesas and SunSPOT sensor nodes employ IEEE 802.15.4 protocol for PHY/MAC layer, however each protocol is only ensured to construct a sensor network within its own vender sensor nodes. One vendor sensor node cannot communicate with other vendor sensor node.

Figure 9 shows the software organization that is required

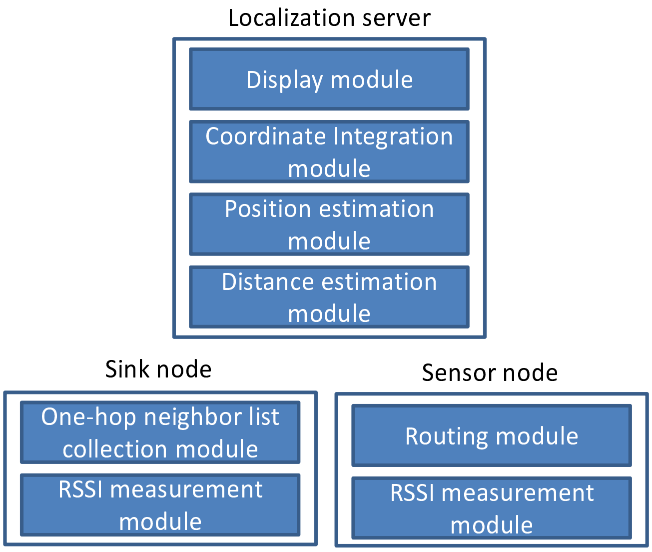


Figure 9: Required functionalities for coordinate integrations.

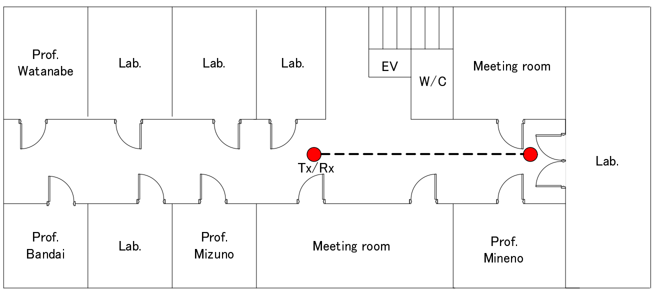


Figure 10: Floor map of RSSI experiment. Location is a corridor on the 4th floor of building in Faculty of Informatics in Hamamatsu campus of Shizuoka University, Japan.

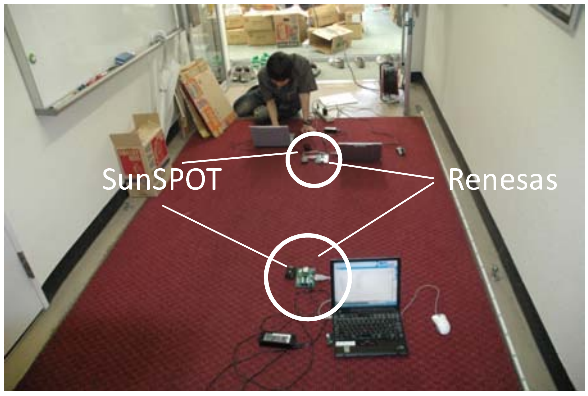
to conduct the proposed integrated coordinates. Three types of nodes, i.e., localization server, sink node, and sensor node are required. We assume that a localization server execute the localization to estimate node positions. In order to conduct localization in multi-hop network, each sensor node needs to have a functionality to hold one-hop neighbor list. Each node is required to have functionalities to obtain RSSI, and relay the RSSI data to a sink node. A sink have the functionality to collect the one-hop neighbor list that is sent from sensor nodes. A sink node connects to localization server, and sends the data to the server. Localization server estimates the distance from RSSI, and calculates node positions. Finally, node positions are displayed. Additionally, a functionality of data exportation of coordinates is required to implement in order to cooperate with other applications.

6 RSSI measurement experiment

6.1 Environments

In our prototype development, a sensor node uses RSSI to estimate the distance between nodes and the position. Generally, RSSI is attenuated when the node distance is longer. Then, RSSI can be used for a parameter to indicate the node distance. The advantage of using RSSI is that it can be extracted for most sensor nodes since RSSI is available if a node has radio capability. Although RSSI can be used for distance estimation, attenuation degree of RSSI depends on multiple factors such as radio frequency and measurement environments. Therefore, we conducted experiments to know how RSSI is attenuated based on node distances. Figure 10 shows a floor map that we conducted RSSI measurement experiments. The experiment location is a corridor on the 4th floor of building in Faculty of Informatics in Hamamatsu campus of Shizuoka University, Japan. RSSI was measured inside the buildings (Fig. 11(a)). The building is made by reinforced concrete. SunSPOT and Renesas nodes were closely placed parallel as shown in Fig. 11(b). We observed RSSI measurements by increasing the distance between transmitter and receiver (Fig. 11(b)). Transmission powers of both nodes were set to -7(dBm). We observed RSSI measurements 1000 times at each measurement points.

(a) Corridor for RSSI measurement



(b) Node placements for experiments

Figure 11: Snapshots of RSSI measurement environments.

6.2 Results

Figure 12 and Fig. 13 shows results for RSSI measurement of Renesas and SunSPOT against the distance. As shown in Fig. 12, most RSSIs of Renesas node were attenuated monotonously as the node distances were longer. The maximum measure-

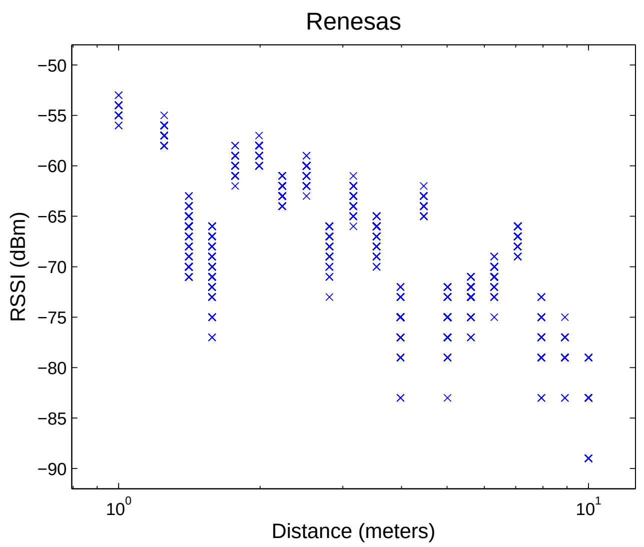


Figure 12: Experimental results of Renesas for RSSI measurements.

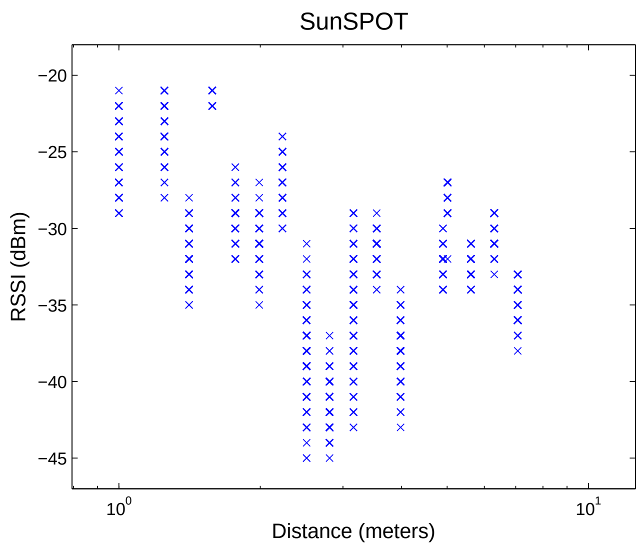


Figure 13: Experimental results of SunSPOT for RSSI measurements..

ment distance to exchange the packets for RSSI measurements was 10 (m). We finalized the experiment at 10 (m) since the packet losses were too many when the node distances were over 10 (m).

It is noted that Fig. 12 and Fig. 13 appear that the number of plotted RSSI points are few. This is because RSSI values obtained from our experimental sensor platforms only read out in the form of an integer value. Much RSSI values are overlapped because of the integer format.

Figure 13 shows results for RSSI measurement of SunSPOT. RSSIs of SunSPOT were also attenuated as the node distances were longer. However, when the node distance was around 3 (m), RSSI was more attenuated than other points, which we could not observe in Renesas node even if the measurement location were same. The result suggests that attenuation of RSSI depends on each vendor of sensor node. The maximum measurement distance for SunSPOT was 7 (m).

RSSI value of Renesas at 1 (m) was -55 (dBm) and RSSI value of SunSPOT at 1 (m) was -25 (dBm) as compared in Fig. 12 and Fig. 13. The result suggests RSSI values are not compatible with vendors of sensor nodes. We need the calibration mechanism to use RSSI values for multi-vendor sensor network environments.

7 Summary

In this paper, we proposed the coordinate integration for heterogeneous network protocols. In the heterogeneous network environments, we revealed an issue that coordinates generated by localization techniques in one network protocol is not compatible with other coordinates generated by another network. This issue is happened when original point for coordinates of anchor nodes is not same as other coordinates of anchor nodes or when the coordinates are relatively determined by using anchor-free localization technique. In such environments, we described coordinate integration that each coordinates can be compatible when at least three share nodes that share the same coordinates are used. We used the simulation to verify that the operations of coordinate integration worked well. Simulation results revealed that placements for shared nodes had impacts on the positioning accuracy in proposed coordinate integrations. We also conducted RSSI measurement experiments inside the university building, and it was revealed that RSSI values were not compatible when vendors of sensor nodes were different.

We are currently implementing functionalities of proposed coordinate integration on Renesas and SunSPOT sensor nodes. In future work, we specify attenuation function of RSSI for multi-vendor sensor networks environments. We plan to evaluate the proposed coordinate integration for heterogeneous network protocol environments in the real environments.

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A Presence-detection Method using RSSI of a Bluetooth Device

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Abstract This paper proposes a presence-detection method using a Bluetooth equipped device. This method overcomes some of the problems with existing products and technologies for detecting user presence (e.g., security threats caused by human error, high introduction cost, and low detection accuracy). The characteristics of the Bluetooth device's RSSI (Received Signal Strength Indication) value were analyzed in preliminary experiments. According to the results of these experiments, the proposed method combines processing using RSSI value threshold and handling of instantaneous variation of RSSI value. The optimum values of the two key parameters used in the combined method (i.e., threshold RSSI value: –22 dB; and judgment time: 7s) were determined by performance evaluation tests, and the effectiveness of the proposed method was verified by simulation.

Keywords: Bluetooth, RSSI, Mobile devices, Information security

1 INTRODUCTION

Nowadays, various information-security measures to prevent the increasing number of threats to security have been tightened. One example is "presence-detection processing" to detect when the user leaves his/her personal computer. Presence-detection is an effective measure for protecting the user's privacy and preventing information leaks and computer abuse by a third party. This measure is necessary not only for campanies but also for the general public. The existing products for presence-detection use USB devises [1] and original radiowaves [2]. These products, however, suffer problems like security deterioration if a key device (authentication key or USB key) is misplaced or lost, high introduction cost, and poor detection accuracy.

The penetration rate of mobile devices has increased year by year [3]. Additionally, most people who have a mobile device also have an internet connected personal computer (PC) [4]. In other words, there is a correlation between mobile devices and PCs. "Bluetooth" is a compact, low-power-consumption, short-range radio technology [5]. These days, many mobile devices support Bluetooth connectivity [6]. Studies on presence-detection using Bluetooth include position detection systems such as Bluetooth-based indoor proximity sensing [7], a location awareness system [8], and delay calculation [9]. These position detection systems are insufficient for presence-detection because they can only detect a small region and are generally very expensive (since they need many devices). Given those drawbacks, the authors have developed a presence-detection system using Bluetooth's received signal strength indication (RSSI) that provides relatively precise detection accuracy at modest cost.

2 PRESENCE-DETECTION METHOD

2.1 Requirement

Presence-detection for a person using a PC must meet the following two requirements. Note that 95% and over of the presence-detection processing must meet the two requirements at once.

<u>Requirement 1: When the user moves away from front of the PC</u>

The PC must run the presence-detection system when the distance between the user and PC is from 10 to 30 m, which was assumed as the best distance range to run the presence-detection system in general.

<u>Requirement 2: When the user is sitting in front of the PC</u>

The PC must not run the presence-detection system when the user is sitting in front of the PC, because it would affect the convenience of user. It is also important to reduce the number of erroneous decisions.

2.2 Methods using Bluetooth

As for presence-detection, the two methods described below are utilized: Inquiry function of Bluetooth (inquiry method) and monitoring communication link (communication link method).

a) Inquiry method

A "master device" is the basic device of a Bluetooth network. A "slave device" is a device connected to the master. The master can get circumjacent slave information (Bluetooth address, Bluetooth clock, etc.) when it runs the inquiry function of Bluetooth.

The inquiry method detects the user's presence by using the inquiry function. The Bluetooth device (i.e., a Bluetooth dongle) of the PC (master) gets the slave information of surrounding Bluetooth devices by running the inquiry function regularly. The PC then judges that the user is sitting in front of the PC if the acquired slave information indicates that the user's Bluetooth device is specified as an

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authentication key (Fig. 1). The existing product BlueLock [10] uses this inquiry method for presence-detection.

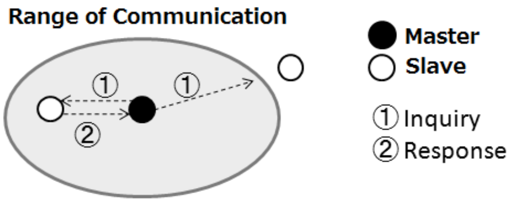


Figure 1: Inquiry method

b) Communication link method

A communication link is data transmission connection between a master and slave for sending and receiving data packets. The master sets up a communication link to a slave by using slave information when the master establishes a connection with the slave, and it controls data transmission to confirm whether the slave can communicate with it.

The communication link method detects the user's presence by monitoring communication links. The PC (master) monitors the communication link when the Bluetooth device connected to the PC establishes a connection with a nearby Bluetooth device as an authentication key (slave). The PC judges that the user is sitting in front of the PC if the Bluetooth device connected to the PC establishes a connection with the user’s Bluetooth device specified as the authentication key(Fig. 2).

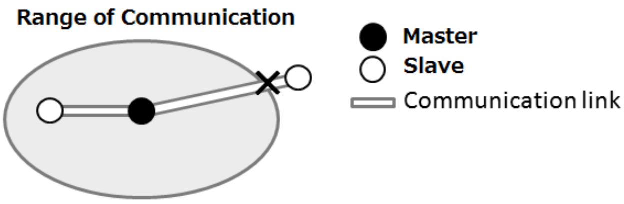


Figure 2: Communication link method

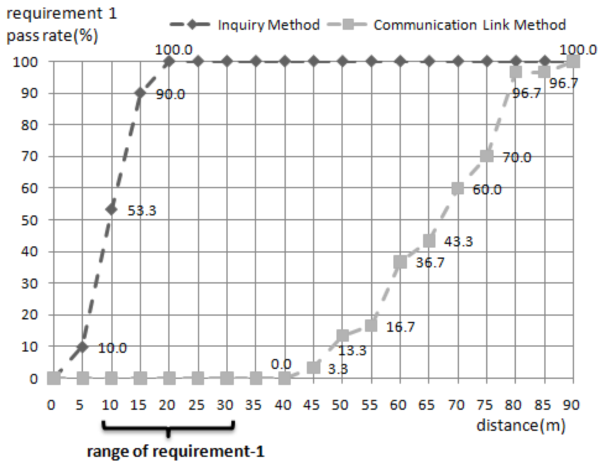
2.3 Performance evaluation

The success rate (pass rate) of the two methods described in section 2.2 in satisfying the two requirements stated in section 2.1 was evaluated. Figure 3 plots the results of a performance evaluation of the inquiry method and communication link method. The commercially available product BlueLock [10] was used to evaluate the performance of the inquiry method, and a program using BlueSoleil6.2 [11] was used to evaluate the performance of the communication link method. A USB Bluetooth dongle (BT-MicroEDR2 [12]) was used as the master device, and a Bluetooth device (HT-1100 [13]) was used as the authentication key in both experiments. The USB Bluetooth dongle was placed on one side of the PC desk.

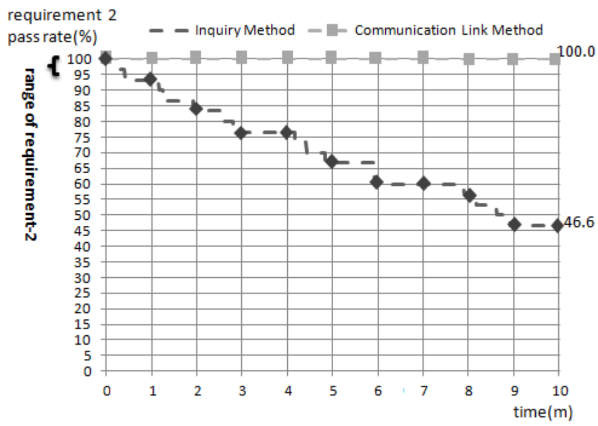
a) Distance measurement

Firstly, a distance measurement experiment with the two methods was performed. This experiment measured the distance between the user and the PC when the inquiry method or communication link method detected that the user had left the PC. The user walked away from the PC at a velocity of 1 m/s. In the experiment, the distance was measured 30 times by each method in three environments (namely, A: a spacious room and metal desk; B: a small room and wooded desk; C: a small room and metal desk). Figure 3(a) plots the relationship between the requirement 1 pass rate (vertical axis) and the distance (horizontal axis) in the distance measurement experiment. The requirement 1 rate is the proportion (in percent) of times out of 30 measurements that the method satisfies requirement 1.It is clear from the graph that either the inquiry method or the communication link method meet requirement 1 if requirement 1 pass rate is over 95%.

The inquiry method satisfies requirement 1, because the requirement 1 pass rate of BlueLock was 100%. In contrast, the communication link method does not satisfy requirement 1, because the requirement 1 pass rate of the program using BlueSoleil 6.2 was zero.



(a) Performance evaluation of distance measurement



(b) Performance evaluation of erroneous detection

Figure 3: Results of evaluations of two methods

b) Erroneous detection

Next, an erroneous detection experiment was performed. In this experiment, the time until erroneous detection occurred while the user sat in front of the PC for 10 minutes was measured. Measurement was performed 30 times while the PC was using either of the two methods in three environments (A: spacious room and metal desk; B: small room and wooden desk; C: small room and metal desk). Figure 3(b) plots requirement 2 pass rate (vertical axis) against time (horizontal axis) for the erroneous detection experiment. If the PC is detecting existence of the user for 10 minutes, the method will satisfy requirement 2. The pass rate in the requirement 2 is the proportion (in percent) of times out of 30 measurements that the method satisfies requirement 2. It is clear from Fig. 3(b) that the either the inquiry method or the communication link method can meet requirement 2 if the requirement 2 pass rate is set to over 95%.

The communication link method satisfies requirement 2, because the requirement 2 pass rate for the program using BlueSoleil 6.2 was 100%. In contrast, the inquiry method does not satisfy requirement 2, because requirement 2 pass rate of BlueLock was 46.6%. These two results indicate that neither method can meet the two requirements at once.

c) Consideration of Performance evaluation

The inquiry method does not satisfy requirement 2, because requirement 2 pass rate of BlueLock was 46.6% (see section 2.3 a). Therefore, the inquiry method may run the presence-detection system when the user is sitting in front of the PC.

In contrast, the communication link method does not satisfy requirement 1, because the requirement 1 pass rate of the program using BlueSoleil 6.2 was zero(see section 2.3 b). Therefore, the communication link method may not run the presence-detection system when the distance between the user and PC is from 10 to 30 m.

These two results indicate that neither method can meet the two requirements at once.

3 PRELIMINARY EXPERIMENTS

3.1 Improvement of two methods

The two methods were improved according to the results presented in section 2.3. That is, the inquiry method with improved judgment conditions was renamed the "advanced inquiry method," and the communication link method with additional comparison processing using received signal strength indication (RSSI) and a threshold value was renamed the "RSSI method".

a) Advanced inquiry method

The advanced inquiry method uses different judgment conditions from those of the normal inquiry method, which judges that the user is sitting in front of the PC if the acquired slave information includes a Bluetooth device specified as the authentication key every time the inquiry function is run. The judgment condition used in the inquiry method is strict inasmuch as this method made erroneous detections (see section 2.3) when the user was sitting in front of the PC. Accordingly, the advanced inquiry method makes the judgment in a different manner, as follows. The inquiry function is run as regularly as done by the inquiry method. If the Bluetooth function of the PC (master) gets the slave information of the authentication key once within a set period of time, the advanced inquiry method judges that the user is sitting in front of the PC. Erroneous detections can be reduced by changing the judgment conditions in this way.

b) RSSI method

In telecommunications, RSSI is a measure of the power of a received radio signal; that is, RSSI quantifies the strength of a radio signal. In general, the value of RSSI decreases as the relative distance with a communication partner increases. RSSI can therefore be used as a measure for expressing relative distance with a communication partner.

In a similar manner to the communication link method, RSSI establishes a connection with the authentication key. The PC then begins to compare the RSSI value and the threshold value that was set for user. The PC judges that the user is sitting in front of the PC if the RSSI value is higher than the threshold value (Fig. 4). The communication link method can be finely controlled by comparing the RSSI and threshold values.

In this study, the RSSI method was chosen because it was thought that it could more effectively satisfy the two requirements than the advanced inquiry method.

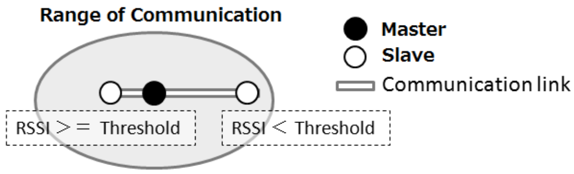


Figure 4: RSSI method.

3.2 Preliminary experiment on RSSI method

A preliminary experiment to determine whether the RSSI method could satisfy both requirements (Section 2.1) was performed first. It was assumed that the RSSI value changes with variations in ambient environment (e.g., desk material, position of Bluetooth dongle, and position of mobile device). In this case, the installation positions of some devices, namely, the Bluetooth dongle of the PC (i.e., the master device) and the mobile device of the user (i.e., the slave device) were different.

Table 1: Average value of RSSI

		Position of mobile device			
		on desk	inside bag	front pocket	back pocket
Position of Bluetooth dongle	direct	-4.6	-17.8	-16.9	-7.6
	side	-9.4	0	-8.8	-0.4
	floor	-21.5	0	-15.0	-18.3
	reverse	-16.8	0	-5.1	-3.8

[dB]

Table 2: Minimum value of RSSI

		Position of mobile device			
		on desk	inside bag	front pocket	back pocket
Position of Bluetooth dongle	direct	-11	-22	-21	-11
	side	-16	0	-17	-5
	floor	-25	-4	-21	-23
	reverse	-23	-2	-14	-9

[dB]

In the preliminary experiment, RSSI value was measured for three minutes when installing the Bluetooth dongle and the mobile device in various positions. Tables 1 and 2 list the average and minimum values of RSSI. The RSSI acquisition program BlueSoleil6.2 base was used to acquire RSSI values.

This program can acquire the integral value of RSSI in the range of about –30 to 0 dB. If RSSI becomes less than –30, the communication link will be cut.) The Bluetooth dongle was connected to the PC at four installation positions: directly to the PC on a desk (Fig. 5: “direct”), to a USB extension cable on the right or left side of the desk (Fig. 6: “side”), on the floor underneath the desk (Fig. 7: “floor”), and on the reverse side of the desk top (Fig. 8: “reverse”). The mobile device of the user was placed in four positions: on a desk, inside a bag, in the front pocket of the user’s pants, and in the back pocket of the pants.

Table 1 lists the average RSSI values for the dongle installation positions and mobile device positions stated above. It is clear from the table that RSSI value tends to differ when the positions of the Bluetooth dongle differ. In particular, when the dongle is positioned as shown in Figs. 5, 7, and 8, the average RSSI value decreases. However, for the “side” position (Fig. 6), the RSSI value is higher than that for the other positions. The relation between RSSI (vertical axis) and distance (horizontal axis) for the side-position case when the user leaves the PC is plotted in Fig. 9(a). The relation between RSSI value (vertical axis) and time (horizontal axis) when the user is sitting in front of the PC is plotted in Fig. 9(b). As shown in Fig. 9(a), when the user leaves the PC, RSSI drops to the range of –25 to –20 dB at 10 to 30 m of requirement. Moreover, as shown in Fig. 9(b), when the user is sitting in front of the PC, RSSI momentarily drops. The position of the mobile device and operation of the user are considered to be the causes of this RSSI drop.

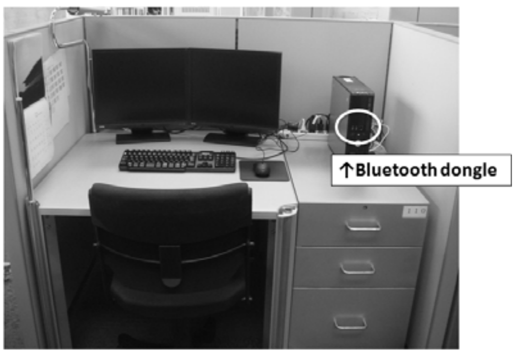


Figure 5: Position of Bluetooth dongle: “direct”

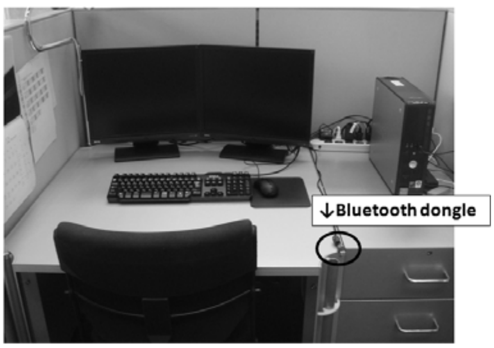
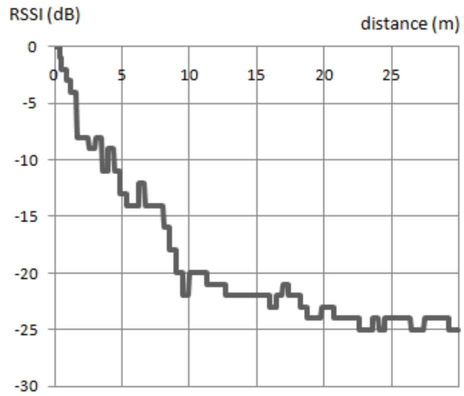


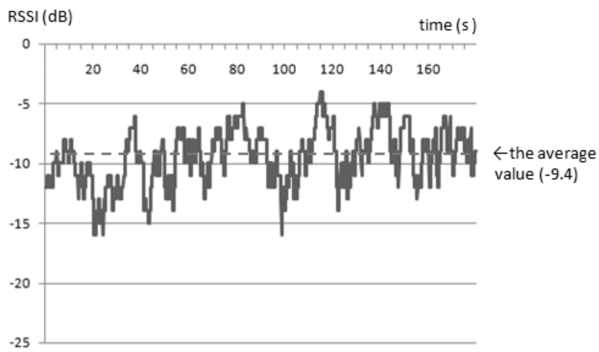
Figure 6: Position of Bluetooth dongle: “side”

Figure 7: Position of Bluetooth dongle: “floor”

Figure 8: Position of Bluetooth dongle: “reverse”



(a) When the user moves away from the PC



(b) When the user is sitting in front of the PC

Figure 9: Examples of variation of RSSI

3.3 Discussion of preliminary experiment

As described in the previous section, it was shown that RSSI value changes significantly in accordance with the position of the mobile device (see Table 1) and suddenly deviates from the average value (Tables 1 and 2). When the user moves away from the desk, as shown in Fig. 9(a), RSSI decreases to about –25 dB. A high RSSI value must be maintained when the user is sitting down in front of the PC. These results indicate that the standard RSSI method (which compares a threshold value with the average RSSI value) may make an erroneous detection when the user is sitting in front of the PC.

The average and minimum RSSI values in the case that the Bluetooth dongle was connected at the desk-side installation position (Fig. 6, "side") are higher than in the cases of the other installation positions ("direct," "floor," and "reverse") regardless of the position the mobile device. The problem of varying RSSI value under different surrounding environments can therefore be solved by connecting the Bluetooth dongle at the desk-side position (because the RSSI value is fairly stable regardless of the surrounding environment). However, since RSSI can drop momentarily, as shown in Fig. 9(b), even if the problem of RSSI-value reduction due to the surrounding environment is reduced, the RSSI method still needs to accommodate the momentary fall in RSSI value.

4 PROPOSED METHOD

4.1 Preconditions

The proposed method is an extension of the RSSI method with the following preconditions added (in accordance with the results of the preliminary experiments described above) and solves the problem of varying RSSI value due to differences in surrounding environment.

Precondition 1: Fixation of installation position of Bluetooth dongle

According to the results of a preliminary experiment, the desk-side installation position of the Bluetooth dongle was selected because the RSSI value is comparatively stable for this position regardless of the surrounding environment and mobile device position.

Precondition 2: Specification of Bluetooth dongle and mobile device

As in the preliminary experiment, a BT-MicroEDR2 (PCI) was used as the Bluetooth dongle and an HT1100 (HTC) was used as the mobile device. Fig. 10 shows the system configuration utilizing these devices.

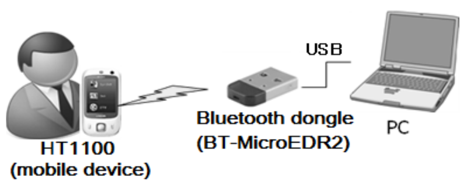


Figure 10: System configuration

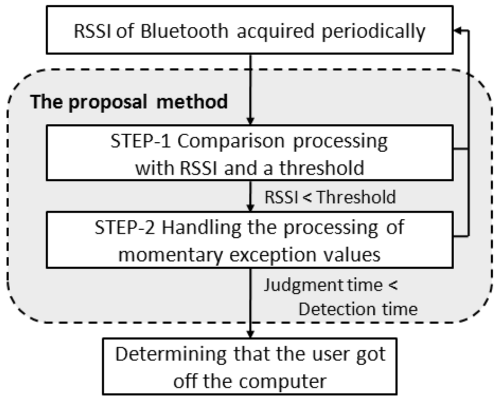


Figure 11: Processing flow of proposed method

4.2 Outline of proposed method

The proposed presence-detection method uses the RSSI function of the Bluetooth dongle to create a system that solves the problems described in Section 3.3 with high detection accuracy at modest cost. Figure 11 shows the process flow of the proposal method, which detects the presence of a user in two processing steps using the RSSI value of a Bluetooth dongle acquired periodically.

STEP-1 Comparison processing with RSSI value and a threshold

Figure 12 shows an example of change of RSSI value (vertical axis) and distance (horizontal axis). The RSSI value decreases, as in Fig. 12, when the distance to a communication partner increases. Accordingly, a threshold that satisfies the requirement 1 is set. The Bluetooth dongle establishes a connection with the mobile device, and the PC compares the RSSI value of the Bluetooth dongle acquired periodically with the threshold. If the RSSI value is lower than the threshold value, the following step (STEP-2 below) is performed.

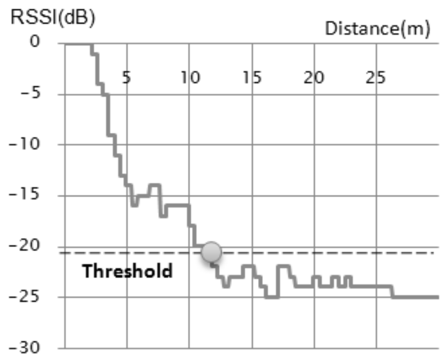


Figure 12: Example of change of RSSI with distance

STEP-2 Handling the processing of momentary exception values

Figure 13 plots RSSI value (vertical axis) against seating time (horizontal axis) in the case that the user is sitting in front of the PC. To satisfy requirement 2, the RSSI value must exceed a certain threshold value like that shown in data1 in Fig. 13. However, an erroneous detection might be included in the comparison processing using the RSSI value and the threshold. At this time, the PC may perform an erroneous detection because of a momentary fall of RSSI value. Accordingly, in the case of the proposed method, additional processing by using a "judgment time" as a momentary exception value is introduced.

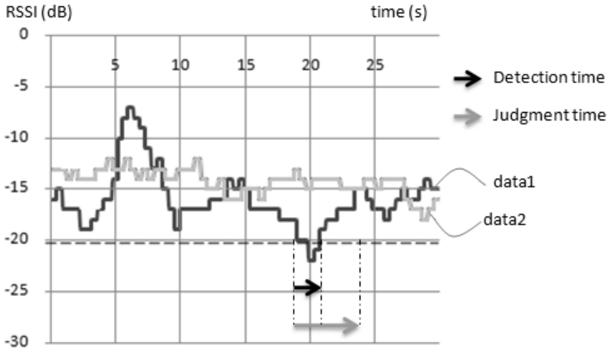


Figure 13: RSSI value against seating time in the case that the user is sitting in front of the PC.

The judgment time is set beforehand as the time that the RSSI value is monitored. In this processing, the PC measures "detection time," that is, the time that the RSSI value is less than the threshold. It then judges that the user has left the PC if the detection time is longer than the judgment time. For example, in data 2 of Fig. 13, although the RSSI value becomes momentarily lower than the threshold, the PC judges that the user is sitting in front of the PC, because the detection time is shorter than the judgment time. Thanks to this additional processing, the proposal method reduces the number of erroneous detections.

5 EVALUATION EXPERIMENT

5.1 Evaluation data

To determine the optimum values of the threshold and judgment time and to verify the usefulness of the proposed method, the following evaluation experiment was conducted. In this evaluation, the RSSI value of the Bluetooth device was obtained during the distance measurement experiment and erroneous detection experiment (see section 2.3) performed under various five experimental environments: A spacious room and metal desk (Fig. 14); B: spacious room and wooden desk (Fig. 14); C: small room and metal desk (Fig. 15); D: small room and wooden desk (Fig. 16); E: spacious room and metal desk (Fig. 17). During the distance measurement experiment, the mobile device was in either of the following six states.

- Held in hand
- Put in front pocket of pants
- Put in back pocket of pants
- Put in a bag
- Sending a text message
- Making a telephone call

In the experiment, a total of 300 RSSI measurement were taken (i.e., five experimental environments multiplied by six mobile device states multiplied by ten times). During the erroneous detection experiment, the mobile device was in one of the following six states.

- Placed on the desk
- Put in front pocket of pants.
- Put in back pocket of pants.
- Put in bag.
- Sending a text message
- Making a telephone call

In the erroneous detection experiment, RSSI value was measured 300 times (five experiment environments multiplied by six states multiplied by ten times).

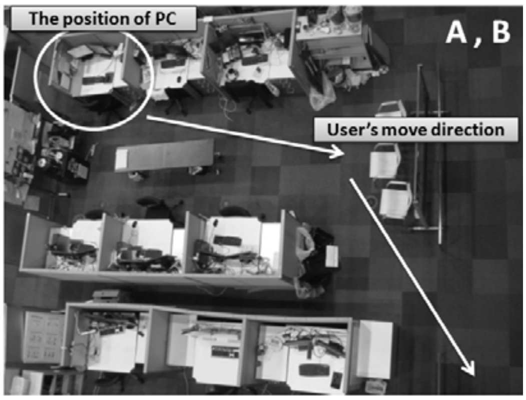


Figure 14: Experiment environments A and B

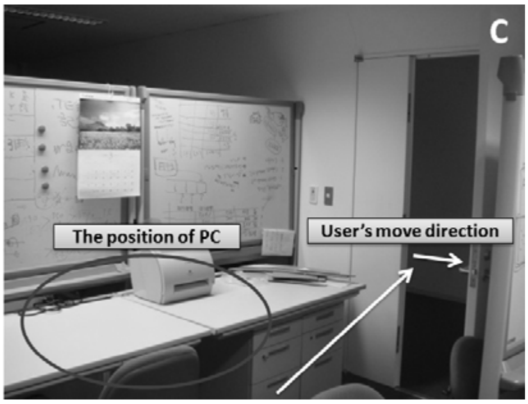


Figure 15: Experiment environment C

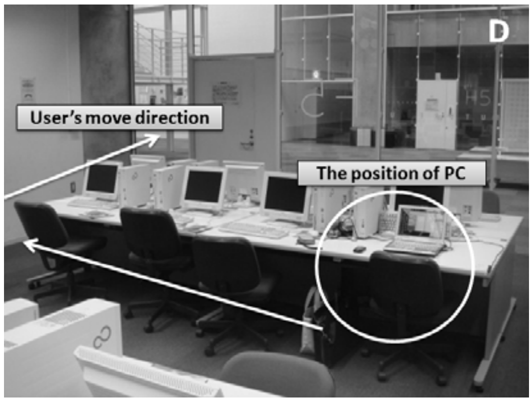


Figure 16: Experiment environment D

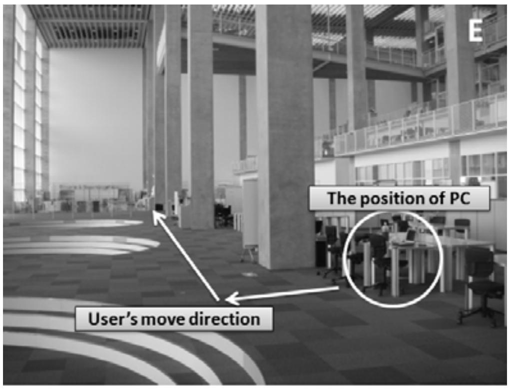


Figure 17: Experiment environment E

5.2 Evaluation simulator

The performance of the proposal method was evaluated by the simulator shown in Fig 18. This simulator outputs the result of the presence-detection by the proposed method using RSSI data (input value). It can freely set the two parameters, such as threshold RSSI value and judgment time, required for the proposal method.

Figure 18: Evaluation simulator

5.3 Performance evaluation

The optimal values of the two parameters (threshold RSSI value and judgment time) were determined from the evaluation data (RSSI values) given in section 5.1. Using these optimal values, the simulator (see section 5.2) was then used to evaluate the performance of the proposal method. There were thirty combinations of evaluated threshold RSSI value and judgment time as listed in Table 3.

First, to evaluate whether the proposal method can satisfy requirement 1 (section 2.1), 300 measurements of the RSSI data acquired during the distance measurement experiment (section 5.1) were analyzed by the simulator. Table 4 lists the analytical results. To meet requirement 1, the PC has to perform the presence-detection processing for 95% (or more) of the time that the distance of the user to the PC from 10 to 30 m. Among the 30 combinations of the two parameters, 14 combinations meet requirement 1 (see Table 3). Moreover, when the judgment time is long, the probability of meeting requirement 1 is high.

Second, to evaluate whether the proposed method can meet the requirement 2, the 300 measurements of the RSSI data acquired in the erroneous detection experiment (section 5.1) were analyzed by the simulator. Table 4 lists the analytical results. To clear the requirement 2, the PC does not have to perform the presence-detection processing for 95% (or more) of the time that the user is sat in front of the PC. Among the 30 combinations of the two parameters, 16 combinations meet requirement 2 (see Table 3). Moreover, when the threshold RSSI value is low, the probability of meeting the requirement 2 is high.

As shown in Table 4, when the threshold RSSI value is –22 dB and judgment time is 7 s, the proposed method meets the first and second requirements simultaneously. Accordingly, this RSSI value/judgment time combination is the optimal one under various conditions. In addition, this result demonstrates that the proposed presence-detection method is highly effective because it can acquire RSSI data in various environments (e.g., various widths of room) with difference states of mobile device. Moreover, the effectiveness of the proposed method was confirmed by simulation utilizing the results of experimental measurements.

Table 3: Combinations of RSSI threshold and judgment time

Th	JT	Th	JT	Th	JT	Th	JT	Th	JT
-20	0	-20	3	-20	5	-20	7	-20	10
-21	0	-21	3	-21	5	-21	7	-21	10
-22	0	-22	3	-22	5	-22	7	-22	10
-23	0	-23	3	-23	5	-23	7	-23	10
-24	0	-24	3	-24	5	-24	7	-24	10
-25	0	-25	3	-25	5	-25	7	-25	10

Th: threshold (dB); JT: judgment time (s)

Table 4: Results of performance evaluation of proposed method

		Judgment time(s)									
		0sec		3sec		5sec		7sec		10sec	
		Req 1	Req 2	Req 1	Req 2	Req 1	Req 2	Req 1	Req 2	Req 1	Req 2
Threshold (dB)	-20	60.7%	**100%**	79.0%	**100%**	85.0%	**100%**	88.3%	**100%**	90.7%	**98.7%**
	-21	68.0%	**100%**	85.3%	**99.7%**	90.3%	**99.7%**	92.7%	**99.0%**	94.7%	**97.0%**
	-22	78.7%	**100%**	90.7%	**99.3%**	93.7%	**98.7%**	**96.0%**	**95.7%**	**97.0%**	92.0%
	-23	83.0%	**99.3%**	94.3%	**97.7%**	**96.3%**	93.3%	**98.0%**	89.0%	**98.7%**	81.7%
	-24	89.0%	94.7%	**98.0%**	88.3%	**99.3%**	82.3%	**99.3%**	77.7%	**99.7%**	70.7%
	-25	**95.0%**	87.3%	**99.3%**	70.7%	**99.3%**	64.7%	**99.3%**	60.7%	**100%**	54.0%

Req 1: requirement 1; Req 2: requirement 2

6 CONCLUDING REMARKS

To develop a presence-detection system with high detection accuracy at modest cost, a presence-detection method using the received signal strength indication (RSSI) function of a Bluetooth device was developed. The performance of this method under various environmental conditions was evaluated by a simulator. According to the evaluation results, when threshold RSSI was –22 dB and judgment time was 7 s, the proposal method met the two specified requirements (section 2.1) simultaneously. It is therefore concluded that the proposal method is effective under various environments. Note that although the types of Bluetooth dongle and mobile device were specified in this study, even if other devices are used, the proposed method can be used by adjusting these two parameters (threshold RSSI value and judgment time).

In future work, the mechanism of automatically setting the parameters of the proposal method in line with user's circumference environment will be investigated, automatic verification of the PC by using a mobile device will be tested, and various applications of presence-detection using the proposal method will be studied. In addition, the advanced inquiry method described in section 3.1 (another proposed method) will be experimentally evaluated.

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An Effective Network Mobility Monitoring Technique with Standardized Protocols

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Abstract - For conventional network management it is implicitly assumed that the managed object will not change its location. So only the static information is available, which is used for simple reporting. The scenario is quite different with mobile devices, as devices are inherently dynamic. It causes difficulties for monitoring processes of management information due to roaming of devices or wireless signal errors. So it has become imperative to review the current approach of network management. To overcome this problem, we propose a new network management technologies based on standard network management protocol. Our focus in this paper is mainly on two items: (i) location awareness, and (ii) intelligent monitoring scheme. Here, we explained about MobileIPv6/NEMO-MIB, which is aware of mobile device's dynamically changing location. We have also discussed about the monitoring scheme of network management information in detail.

Keywords: MobileIPv6, NEMO, SNMP, Mobility

1 Introduction

Location of managed object is implicitly assumed as static for traditional network. The location related information, if available is static and its use is limited to reporting purposes. However, with mobile devices these attributes are inherently dynamic. So, it is important for network management to understand the dynamics of location of devices for planning, administering and controlling a network. When planing, distribution or managing configuration of parameters in mobility protocols, density, roaming frequency and visiting duration of devices in the network are the important pieces of information. So it is essential to review the current approach of management and further reconsideration is required for configuration, operations, performance and security management.

The basic concept of *reachability* has changed due to the introduction of mobility of devices. An IP network can be connectionless and the routes may change dynamically. But in conventional thinking, under normal circumstances network devices are considered to be reachable. The same assumption is extended to the manager-agent management framework as well. In monitoring process, polling at a regular interval is conducted to collect management information. This interval is generally set larger than the response time, so that the time stamp of the polling request or the response can be considered as the time-stamp of the information.

There is a wide fluctuation of response time in mobility aware networks due to the instability of reachability and this can cause severe degradation of quality of collected information. Though there are certain conveniences of network mobility, considering NEMO environment, but optimized route can not always be used. In that case, the amount of polling traffic could be substantial. With available bandwidth for wireless network is usually narrow, it can cause severe network congestion on certain links. In this paper, we propose a network management framework, which takes into consideration the inherent dynamic nature of location and the instability. The rest of the paper is structured as follows. In Section 2 we describe the problem statement. In Section 3 we presents our proposal on MobileIPv6/NEMO-MIB and two monitoring schemes. Evaluation is discussed in Section 4 and related works are described in Section 5. Finally we conclude our work in Section 6.

2 Problem Statement

2.1 Network Model

MobileIPv6[1] and NEMO (Network Mobility Support)[2] realize node and network mobility in IPv6 Internet.

The MobileIPv6 architecture is described in terms of three types of entities: mobile node (MN), correspondent node (CN) and home agent (HA). When a MN roams from one network to another, the IP address changes. This address is called Care-of Address (CoA). Each MN has its own IP address authorized by its home network, and called Home Address (HoA). When CoA of MN changes, MN registers it to HA with HoA. HA maintains the registered CoA/HoA sets of MNs. It is called *binding cache*. When packets from CNs destined to HoA come, HA forwards them to the registered CoA.

NEMO is a simple extension of MobileIPv6, adding an entity called mobile router (MR). A MR is basically a router with the additional functionality of mobility support that normal routers does not have. A MR registers its network prefix to the binding cache. The prefix is called Mobile Network Prefix (MNP). Nodes connected to MNP can have mobility with MR.

In this paper, we call MN and MR as *mobile devices*. Both MobileIPv6 and NEMO enable global mobility of mobile devices with no restriction of area.

2.2 Needs of New Management Framework

Generally management of network devices is carried out by monitoring or setting the value of a "Managed object(MO)". MOs are accessed by SNMP. The traditional SNMP-based network management adopts *manager-agent management framework*. Agents that employ MIBs are monitored by a manager or managers using SNMP. Fig.1-(a) shows the overview of this framework. Fig.1-(b) describes two additionally needed extensions, to take into consideration the inherent dynamic nature of location and the instable nature of network reachability.

First, for all practical purposes, the scope of the concept of location in traditional network management has been limited to the "sysLocation" in the MIB-II [3] that is the MO provided static descriptive value. The traditional MIB-II is insufficient for managing dynamic nature of location because the location of a device changes dynamically in networks that support mobility. So the new MIB should be aware of inherent dynamic nature of location of devices. Thus *location-aware* MIBs will be needed. Main concern is the concept of location of the mobile device, and how to monitor and track the device locations monitored continuously especially in MobileIPv6/NEMO environment. In section 2.3 we consider how to monitor the location of mobile devices.

The second need is to overcome the instable nature of network reachability. Monitoring process is crucial for many types of management information, because the change in the values of the MOs with time is of key interest. Monitoring performance of mobility protocols, mobile devices and applications on the devices is an important aspect of network management. Location information also should be monitored. It is important to carry out periodical and continuous polling precisely. But the wide fluctuation of the response time between the manager and the agents caused by roaming of the device is unavoidable. The transient failure of wireless links will cause large number of packet losses. SNMP polling suffers from several polling timeout and they degrade the quality of collected management information. It is difficult to maintain a simplified monitoring process. Monitoring process should be more *intelligent* to overcome instability of the reachability. In section 2.4 we consider about this problem and propose a novel technology for continuous device monitoring over an instable network.

The new dimensions, *location-awareness*, and *intelligent monitoring scheme*, added to networking by mobility require extensions to the traditional network management framework.

2.3 Location-awareness

We classify the concept of location of a mobile device based on these three aspects:

- Organizational Location: the administrative domain to which the mobile device belongs.

- Segment Location: the subnetwork to which the mobile device is attached.

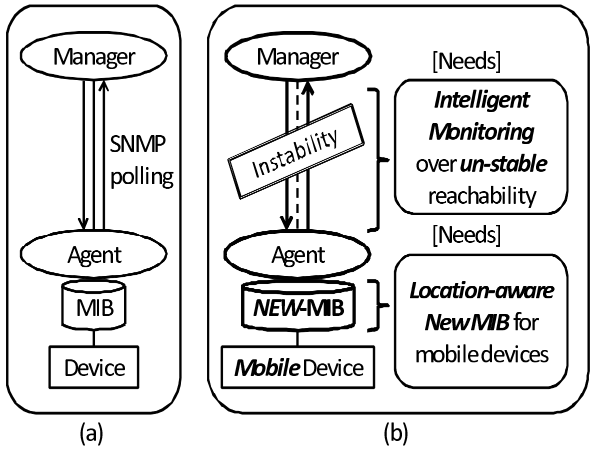


Figure 1: Manager-Agent management framework using SNMP (a)Traditional management: Manager monitors device's MIB. (b) Extensions needed: 1) new location aware MIB of mobile device and 2)intelligent monitoring scheme that realize monitoring over instable reachability.

- Geographical Location: the longitude, latitude, altitude information of the mobile device.

In the traditional network, all aspects of location of a device are fixed. Fig.2 describes three separate scenarios of location changes for mobile devices in MobileIPv6/NEMO network environment. We can see that device and network mobility allows three different location aspects to change independently.

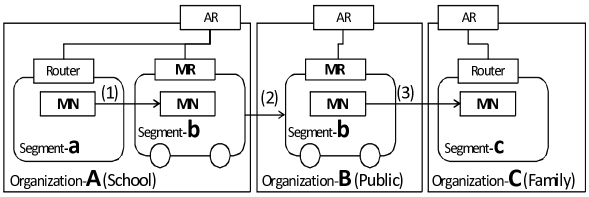
In scenario type-(1) the MN moves from a segment under a router (inside the school) to the other segment which is under the MR (mobile router deployed inside the school-bus) within the same organization (school network). In type-(2) the MN itself does not move, the MR leaves from one organization (school network) and connects to the other organization (public network). In type-(3) the MN moves from the segment (school-bus network that attaches to the public network) to another segment that belongs to a different organization (family network).

As described above, these location changes occur dynamically and independently, sometimes without user's intention. Looking current locations of mobile devices enables managers to get the current view of their managing devices, and the network.

2.4 Intelligent monitoring scheme

It is important to carry out periodical and continuous polling precisely in monitoring process. However, in general the concept of "time" in traditional monitoring does not have an exact definition.

As Fig.3-(a) shows, in some cases it is the time when the request was sent by a manager. In others it is the time when the response is received. It is considered to be an unnecessary overhead to tag every observation with the actual time of the observation. In traditional networks the RTT between the manager and the monitored agent is generally of the order of 10ms. On WLANs it can goes upto the order of 100ms. The polling interval t is of the order of several seconds. So,



Location of Device	Organization	Segment	Geographic
Type-(1)	Unchange (A->A)	*Change(a->b)*	*change*
Type-(2)	*Change(A->B)*	Unchange(b->b)	*change*
Type-(3)	*Change(B->C)*	*Change(b->c)*	*change*

Figure 2: Three types of location changes in a mobile node: Organization/Segment/Geographical location changes occur separately.

the inaccuracy introduced in the time-stamp may considered to be negligible. But in a mobility-aware network, the RTT may vary widely. Typical latency of hand-over within same wireless access media is 300-500ms (L2 movement), and at least 3 seconds (L3 movement) [4] without any optimization. Thus information collection by polling at *regular intervals* in the traditional mode may cause an accuracy degradation of periodical information. Additionally, a traditional SNMP manager uses RTT information to fix the polling timeout. In the case of periodical polling, this approach results in a large number of timeouts and consequent data loss in data collection. This causes severe degradation in the quality of collected information.

To overcome these problems, we had previously proposed the *timestamped monitoring technique*. Fig.3-(b) shows the brief structure of this technique. The *bulk retrieval technique* can be realized with *timestamped monitoring & buffering* proposed in [5] to solve the problem of data loss. Data buffering at the agent-side recovers data losses in polling.

In NEMO environment, where route optimization is not supported, all packets toward MN are forwarded through HA because packets from Manager to MN are encapsulated in bi-directional tunnel between HA and MR. Therefore transferring the excess of management information may causes performance degradation of HA network. So, if possible, it would be better to monitor MN without going through this tunnel, i.e connect directly. When MobileIPv6 supports route optimization, manager just monitor the MN.

Fig.4 explains another problem intuitively. During MR's long term disconnection, there will be large amount of data buffered at agents. Just after reconnection, agents may send them all together and there will be a sudden surge in monitoring traffic. It causes congestion of MR's upstream link and may seriously affects other communications of MNs. If MR moves into a narrow bandwidth environment, the effect of this problem become severe. We need to control the timing or the amount of monitoring traffic to avoid this. Also, since the number of MNs are much larger than the HAs, the influence of managed data collected from HA should be much smaller than the MNs/MR. Therefore, we mainly focus on the cases where managed objects are collected from MNs/MRs and not from HA.

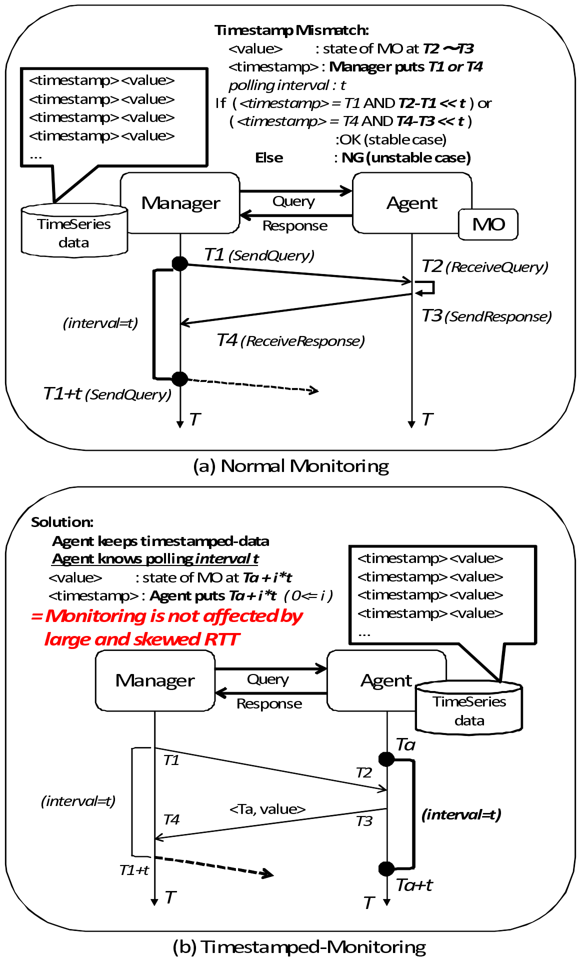


Figure 3: Timestamped monitoring - (a) Normal periodical monitoring contains risk of time-stamp mismatch (b) Agent itself puts time-stamp

3 Proposal

3.1 MobileIPv6/NEMO-MIB

Since we are trying to develop SNMP-based monitoring environment to manage the location as the three scenarios discussed in Section 2.3, pre-defined Management Object is needed. Therefore, we proposed *MobileIPv6-MIB* [6] and *NEMO-MIB* [7] objects in the MobileIPv6/NEMO-MIB as shown in Table 1. The kinds of Managed Objects at HA/MNs/MRs/CNs are decided according to the functions of mobile devices. For example, since MobileIPv6 Binding Update Requests that have been received and accepted are managed by HA and CN; managed objects for them called *mip6BindingCacheTable* and *mip6BindingHistoryTable* and are placed on MIB agent at HA and CN. Other objects are also placed in the same way.

A mobile device's global address (CoA) potentially reveals address of the network to which the device is attached. Thereby, the location of the mobile device (the organization and/or the segment that the device exists in) can be traced. Location information can be collected from *binding information* available at the HA that is communicating with the mobile device (MR/MN).

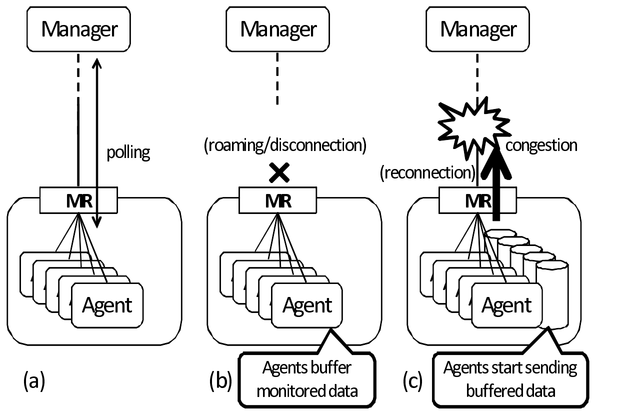


Figure 4: (a) Normal polling (b) Agents buffer data during MR's disconnection (c) Data sending after reconnection causes a congestion of MR's upstream

The MobileIPv6/NEMO-MIB can provide location information of mobile devices, by using MNPs of MRs and MR/MN's CoAs. MobileIPv6-MIB is the MIB module for MobileIPv6 entities. *mip6BindingCacheTable* reveals the binding cache information of MNs that is maintained in the HA (or in the CN). This reveals the segment where the MN is connected. If the prefix of the CoA is from static network, the organization where the MN is connected is also revealed. *mip6BindingHistoryTable* has the expired binding cache information. We can track the movement of mobile devices from the history. *mip6MnBLTable* is the list of binding update that is maintained by the mobile device itself. It shows the attempts of binding update by the MN. It is possible by using this table to get information of CoAs even after some binding updates had been failed. *NEMO-MIB* is the MIB module for NEMO entities. *nemoBindingCacheTable* is extended with *mip6BindingCacheTable*. It will serve the segment/organization information of MRs. NEMO-MIB also defines the *nemoHaMobileNetworkPrefixTable* that contains information of the registered MNP in the MR's network. If the mobile device has the CoA from the MNP, it can be revealed that the mobile device is connecting to the MR's segment.

These give rise to a new area of management - *location management*, wherein the location of a mobile device is monitored, analyzed, utilized and controlled, as new applications are emerging in this area. It helps to diagnose the cause of the faults, performance degradations, and so forth. Managers have to find and monitor changes in these locations all the time.

3.2 Direct Monitoring

To collect management information effectively, we propose a direct monitoring method which stores the managed information on MR for MNs.

In NEMO environment which does not support route optimization, packets from Manager to MN are encapsulated in bi-directional tunnel between HA and MR. As all the packets toward MN are forwarded through HA, manager can not connect MN directly. As manager can connect CoA of MR directly, in our proposed method we are considering about fetching the management information of MN through MR.

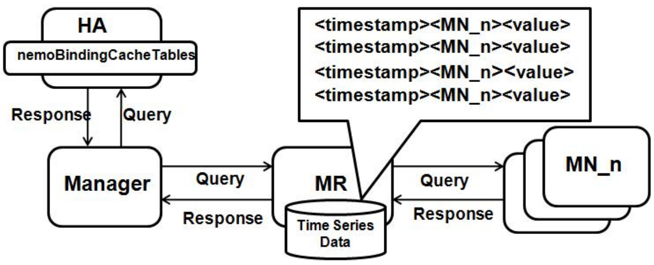


Figure 5: Overview of direct monitor method

Fig.5 illustrates the overview of the direct monitoring method. At MR we use buffering scheme like mobisnmp[5]. Its managed values are buffered not only time-stamp but also identifications of each MNs. Here MR periodically monitors the managed value from MN and store it in its buffer. When manager tries to request the buffered managed information, first, the manager picks up a MR's CoA in the nemoBindingCacheTables of HA's NEMO-MIB. Then it collects managed information buffered in MR. Since MR's CoA may change frequently, manager always makes continuous efforts to pick it up. This method can omit wasted managed traffic, and thus can lead to higher performance, especially when bandwidth of HA is narrow.

3.3 Delayed Data Sending Method

We propose a novel method to prevent congestion on MR's upstream link caused by SNMP agents that buffered large amount of management information and send them at a burst. We call this method as *delayed data sending method*. The idea is illustrated in Fig.6. This method is based on direct monitoring method.

The MR monitors the polling interval that managers requests for managed information. When the MR's upstream link is disconnected, it also monitors the duration of its disconnection. The MR has the configured value of L. L is the permitted ratio of MR's upstream bandwidth U for monitoring. Monitoring traffic can consume at most $U * L$. This value is configured to avoid congestion of the upstream link. The MR estimates the amount of monitoring traffics to be transmitted after the upstream is reconnected. If monitoring traffic M assumes to exceed the limitation $U \times L$ during next transmission, proposed method decides how much transmission should be delayed and how many times information data should be divided so that monitoring traffic would not exceed the limit.

Considering the interval of monitoring traffic, amount of its traffic, and disconnection duration, MR estimates the amount of monitoring traffic traveling through MR at each time. If total amount of monitoring traffic M assumes to exceed the limit $U \times L$, MR delays and divides the transmission into blocks with the following procedure. In our scheme, we take this approach so that each traffic will be distributed fairly.

If monitoring traffic exceeds the limitation value of $U \times L$, MR at first divides the information data into $\lceil M/U \times L \rceil$

Table 1: Managed Objects in MobileIPv6/NEMO-MIB related to location management

	Name of the object	*Entities to maintain*	*Description*
MobileIPv6-MIB	mip6BindingCacheTable	HA/CN	Models the Binding Cache
	mip6BindingHistoryTable	HA/CN	Tracks the history of the Binding Cache
	mip6MnHomeAddressTable	MN(MR)	List of Home Addresses pertaining to the MN(MR)
	mip6MnBLTable	MN(MR)	Models the Binding Update List
NEMO-MIB	nemoBindingCacheTable	HA	Extended Binding Cache in NEMO
	nemoMrBLTable	MR	Extended Binding Update List in NEMO
	nemoHaMobileNetworkPrefixTable	HA	List of Mobile Network Prefix registered by HA

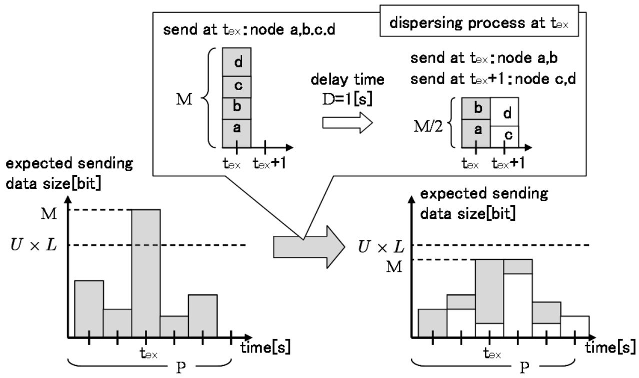


Figure 6: Delayed data sending method

blocks, for example, B_1, B_2, B_3. Then transmission time of divided blocks are arranged so that B_2, B_3 will be transmitted at $t+u$, $t+2u$, where t is the transmission time of B_1 and u is the unit of time. If maximum amount of arranged monitoring traffic M still exceeds the upper bound limit of $U \times L$, then each block of transmission is divided into two. Then transmission time of divided blocks are re-arranged again. In spite of the adjustment, if it exceeds the limit, MR plans to divide block of transmission into three. In this way, re-arrangement of the delay and division of the transmission will be done repeatedly until maximum amount of monitoring traffic M is less than the limitation $U \times L$. A more detail description of our method can be found in [8].

Fig.6 shows a very simple case to explain it. There are 4 nodes, a, b, c and d. In this case, for node c and d, MR waits for 1 sec to send the data. As a result, M has been successfully controlled not to exceed the limit ($U * L$). In this way, delayed data sending method can control transmission for large amount of buffered management data effectively. If MR moves into a narrow bandwidth environment, our method becomes more effective.

4 Evaluation

4.1 Experimental Environment

We build an experimental MobileIPv6/NEMO network in our laboratory, using SHISA [9], one of most widely-used MobileIPv6/NEMO implementations. Fig.7 shows the structure of the network. IPv6 is deployed in the entire network. One single MR is attached with a few MNs. It can moves from one network to another. Each network has an Access Router (AR).

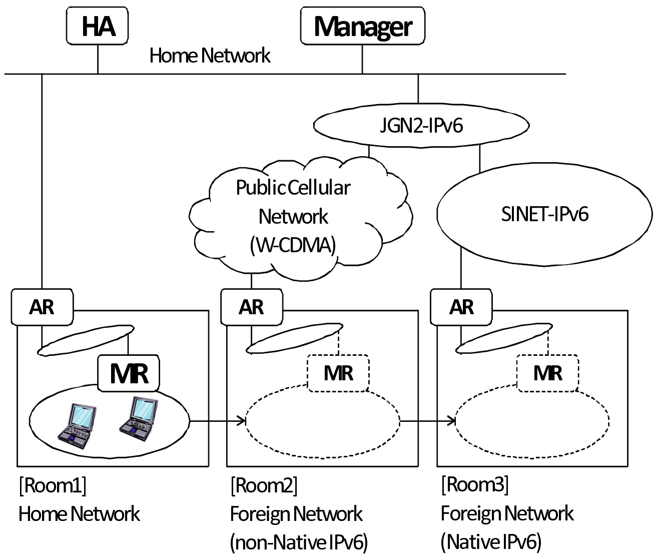


Figure 7: Topology of the experimental network: It includes 2 foreign networks: the native-IPv6 network and the cellular network which is non-native-IPv6 network.

There are 3 rooms, each room has different types of access network. In Room-1 the AR connects to the home network, that is, where the HA of MR exists. Its structure is almost same as a simple LAN. The IPv6 upstream of our laboratory is *JGN2-IPv6*. In Room-2, it is a foreign network, and the upstream is via cellular network. Here IPv6 connection is non-native, that is, the IPv6 connection is provided by tunnel technology. Also Room-3 is a foreign network but here it natively connects to IPv6. It connects to the *SINET-IPv6*. In Room-1 and Room-3, ARs are wire-connected. But in Room-2, the AR has a cellular network interface and is connected with the wireless link. These networks can be divided according to its performance. In Room-1 RTT and packet loss rate between HA and MR is low. In Room-2 the RTT between HA and MR is big and there can be high packet loss. In Room-3 packet loss rate between HA and MR is low, but RTT is medium. In this experiment, MR stays in Room-1 for 30 sec. Then MR moves from Room-1 to Room-2 and stay for 60 sec. Finally it moves from Room-2 to Room-3.

4.2 Binding related data collection using prototype system

Fig.8 shows the result of polling by the prototype SNMP manager from the prototype MobileIPv6/NEMO-MIB mod-

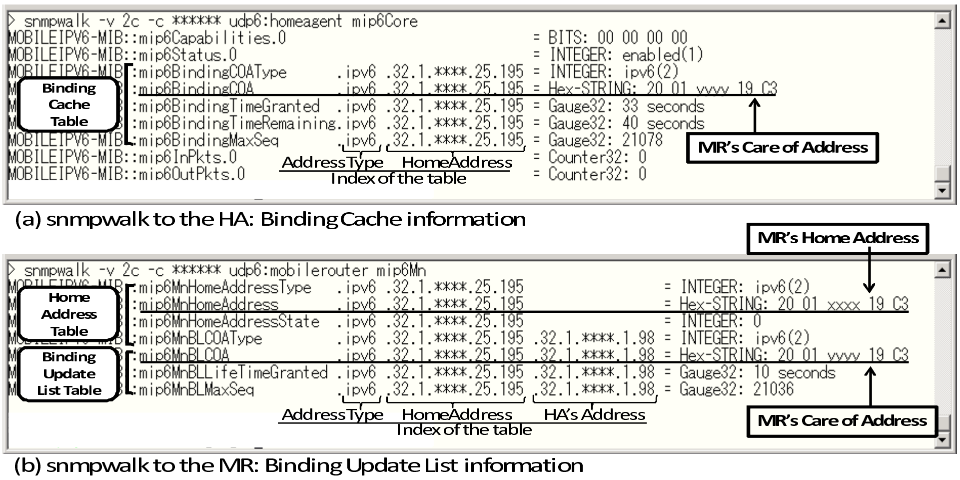


Figure 8: Screenshot of SNMP polling of the implemented prototypes in Room-2

ule implemented in SNMP agents running on HA and MR when MR stays in Room-2. Fig.8-(a) shows *mip6BindingCacheTable* (ensure consistency binding cache table) from the HA. Fig.8-(b) reveals *mip6MnBLTable* (binding update list table) collected from the MR that corresponds to (a).

We confirmed that the manager can get correct information about bindings from MIB modules in every case that the MR/MN connects to one of the 3 rooms in our experimental network. This result proves that our MIB implementation can provide correct binding related information to managers without serious trouble, in a reasonable MobileIPv6/NEMO environment.

Besides, we confirm the consistency of SNMP agent's information between HA and MR. Comparing with Home Address of in MR in Fig.8-(a), we can obtain MR's care of address from HA's mip6BindingCacheTable. By another way by using snmpwalk to MR, MR's care of address can be also obtained from the mip6MnBLTable in Fig.8-(b), because MR is equivalent to be MN in MobileIPv6 protocol. Additionally, MR's HomeAddress is same as that of Fig.8-(a). These results proves that our prototype system can keep consistency with obtained information from HA and MR.

To our knowledge, this is one of the pioneering work on implementation of MobileIPv6/NEMO-MIB. It demonstrates the feasibility of monitoring mobile devices using the Internet standard network management protocol, SNMP. Apart from the traditional traffic or configuration information, the MobileIPv6/NEMO-MIB does contain information that provides location information in one form or the other for monitoring mobility. Information that can be collected from MobileIPv6/NEMO-MIB is mandatory in developing new management applications for location-aware network management in MobileIPv6/NEMO network. The example of application is explained in section 4.4.

4.3 Delayed data sending method

To verify the effectiveness of our proposed *delayed data sending method*, we compared the performance by using ns-2 [10].

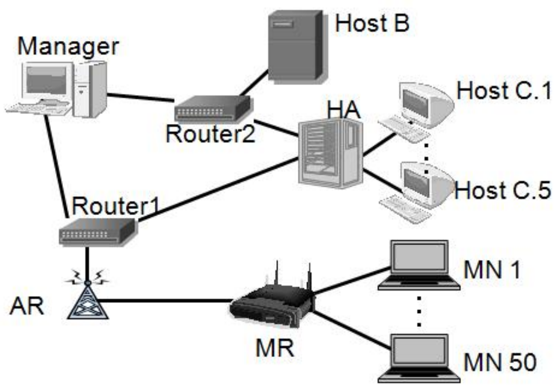


Figure 9: Simulation environment

Simulation environment is shown in Fig.9. There are 50 MNs connected under the MR. We configured that, 1) manager polls MOs in 30 sec interval, 2) each MN collects 10 MO per 5 sec, 3) the size of each MO is 100 bytes, 4) five hosts (C1, C2, C3, C4 and C5) are connected at HA to produce background traffic toward host B, 5) MR's bandwidth between AR and MR is configured as 11 Mbps, and others are set at 50 Mbps. Simulations time is 600 seconds. To increase the amount of monitoring bursty traffic, link between MR and AR goes down from 90 to 210 sec.

In the above described environment, two kinds of simulation scenarios are examined. In scenario (1), VoIP traffic is transmitted from one of the MN to Host B at 1Mbps. In scenario (2), five hosts (C1, C2, C3, C4 and C5), which are connected under HA, transmit traffic to B at 10 Mbps respectively. The limiting value L, the permitted ratio of MR's upstream bandwidth U for monitoring, is configured as $0.1 (= 10\%)$.

By scenario (1), we confirm that proposed method can keep the monitoring traffic to a constant level and lead to the reduction of interference on VoIP traffic in terms of throughput and jitter.

Fig.10 shows monitoring traffic during simulation. Traffic details just after the re-connection is shown in Fig.11. These

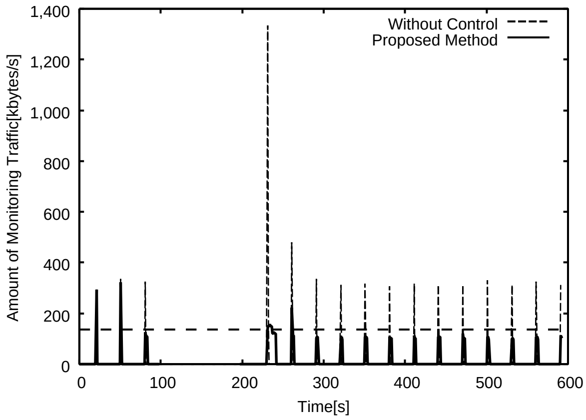


Figure 10: Monitoring traffic from 0 to 600 sec

graphs show that, without controlling, the amount of traffic violates the limitation. On the other hand, our proposed method hardly exceeds the limit. Therefore our proposed method can effectively distribute bursty management data transmission for avoiding congestion on upstream link of MRs.

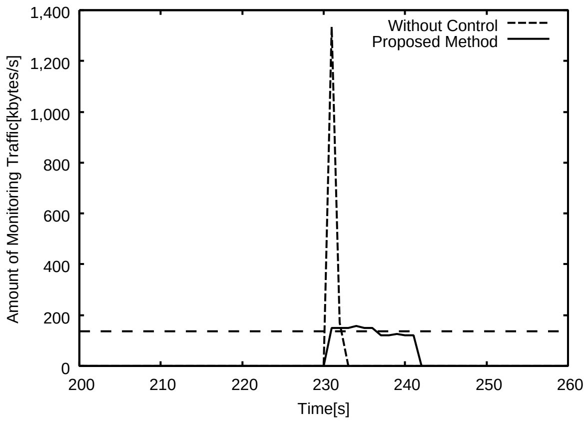


Figure 11: Detail of monitoring traffic right after the link between MR and AR has recovered

To confirm that proposed method can reduce the interference on VoIP between MN and host B, throughput and jitter of VoIP are measured as shown in Fig.12 and 13. These results show, that by suppressing the amount of monitoring traffic to a lower level, proposed method can enable VoIP not only to achieve higher throughput but also can keep jitter low. Therefore, the proposed method can reduce the interference on other traffic under MR during monitoring.

Finally, to show the effect of direct monitoring, we measure the traffic from one host connected under HA to host B. Traffic on host C3 and host C4 is shown in Fig.14 and 15 respectively. Both results show that proposed method is free from interference of monitoring traffic, and thus achieved higher throughput. This means proposed scheme is capable of reducing the interference on HA traffic effectively.

Through these results, our proposed scheme shows it can solve the congestion occurred at MR. Additionally the scalability in terms of processing is an important factor. In NEMO environment, Mobile Nodes under MR assume to be small devices like living sensor which only supports IPv6 protocol

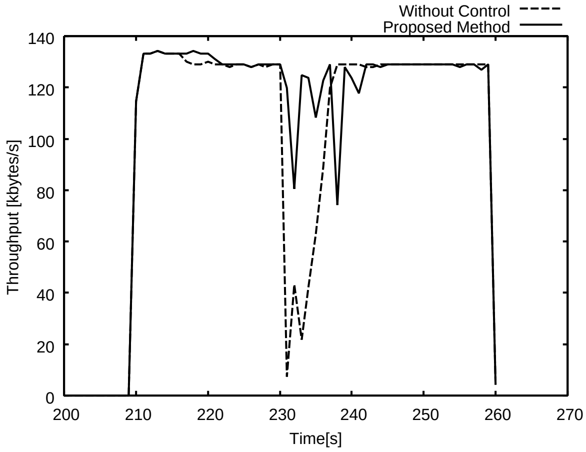


Figure 12: Comparison of throughput when the transmission is between MN to host B

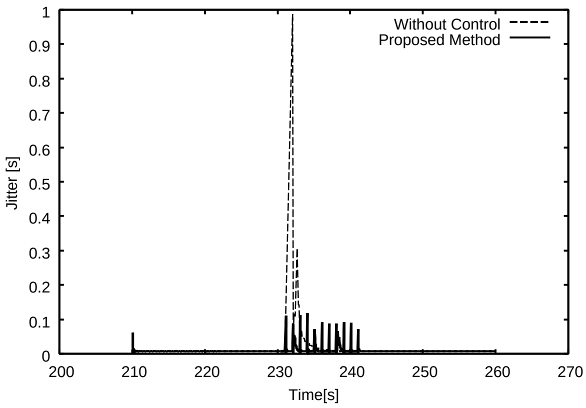


Figure 13: Comparison of jitter when the transmission is between MN to host B

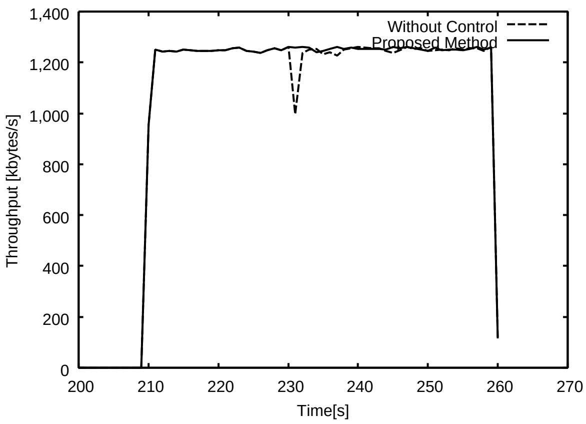


Figure 14: Comparison of throughput when transmission is between C3 to host B

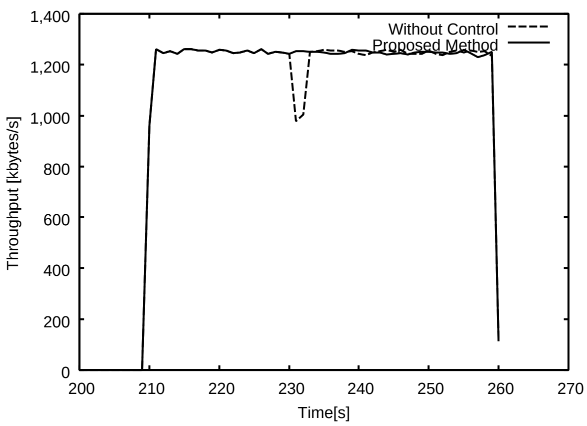


Figure 15: Comparison of throughput when transmission is between C4 to host B

and SNMP function to provide Manage objects. It is desirable to store and coordinate the timing to transfer the data of Managed Object by MRs but not MN which has higher performance than MN. As for storing Managed data, our previous work to store the Managed Object in [5] shows its adverse effects are nominal. So it is also valid for this work. Regarding the influence of delayed data sending method, it should be examined in details. There are many ways to reduce its workload, and we will consider them as the future extension of this work.

4.4 Effective management application using location

As explained in this paper, the location-awareness and the intelligent monitoring scheme are novel and important axes of network management technologies.

In this section we explain about the example application now we are constructing.

The application will be different from the traditional simple demonstration of network traffic and configuration information. The application uses location information to track the path of a mobile device. The MobileIPv6/NEMO-MIB modules can provide information of the network that the mobile device is currently connecting. It also provides the list of networks that the mobile device had been connected in the past. Three types of location of the mobile device can be determined with reasonable accuracy using other MIBs that service geographical location information like GPS-MIB. This opens up a new vista of tracking mobile devices for management. The application also shows how the path of a mobile device can be tracked even when it is out of network reach. It demonstrates that mobility-aware networks can be managed by using already standardized and widely utilized management protocol same as any other device and network. The mobility related status, parameters and metrics can be evaluated. The traffic can be monitored and the network configuration can be discovered.

We envisage the application that supports dynamic network topology visualization. Fig.16 is a screenshot of the application. In this image, a MR is deployed on a public transport, like bus. GPS equipment is connected to the MR and it makes

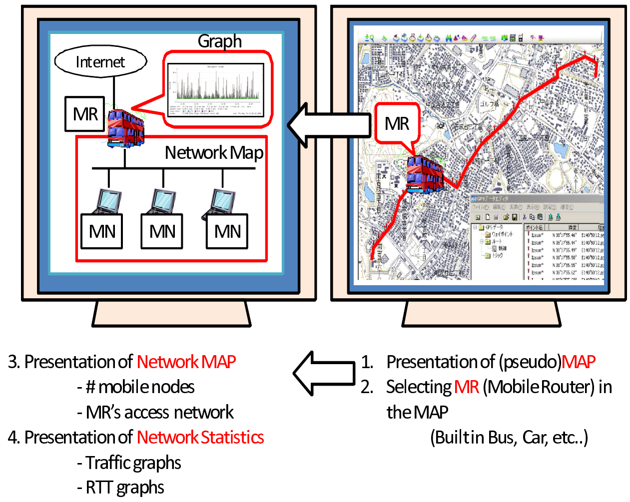


Figure 16: The screenshot of the application that realizes location-aware network management

possible to locate the bus on the geographical map. It works only as an interface to point out for human managers that manages MRs. When a human manager points the bus, the application shows the information of the MR and its network.

By using the information from MobileIPv6/NEMO-MIB, it is possible to show the network where the MR is attached now. The information of MNP shows prefixes that is reachable under the MR. It is also possible to show the number of MNs connected to the MR. These functions reveal the network topology of MR's network. Traffic information of MR's network is also possible to provide. We ensure that our proposed MobileIPv6/NEMO-MIB overcomes to track the device locations monitored continuously.

5 Related works

To reduce congestion Teo et al. [11] proposed a dispersing scheme of monitoring the traffic by using multiple paths. But it is hard to apply a similar method to NEMO environment where MR may not always have multiple paths, i.e. multiple access router. In [12], distinguishing the monitoring traffic according to pre-provided priority of the packet and nodes, traffic is controlled to avoid congestion. Although this scheme can not be applicable into NEMO environment because monitoring traffic can not be distinguished explicitly according to the MNs's managed object. There are several schemes to reduce the amount of traffic. Well-known Snmp bulk scheme to get traffic in single request can surely reduce the amount of traffic. Although without coordinating the timing of transmissions, fundamental congestion problem that the traffic MN are sent at one time from multiple sources can not be solved. [13] proposed a scheme to transfer managed data from agent to the manager at regular intervals. Its effect is trivial to reduce the congestion since only the amount of requested traffic from manager can be reduced. In [14], it estimates and controls the congestion according to the status of nodes and network. This kind of idea can be applicable to NEMO environment. Through this discussion, we can assume that dispersing the monitoring traffic at MR based on the estimation of the amount of traffic as we proposed is desirable.

6 Conclusion

For a new network management technology of MobileIPv6/ NEMO network environment, we propose a *location aware* and intelligent monitoring scheme. We explained about the *MobileIPv6/NEMO-MIB* which is aware of mobile device's inherent dynamic nature of location, and we introduce an intelligent monitoring scheme. This is one of the first applications for monitoring mobile devices and networks that are entirely based on Internet Standard network management protocols of MobileIPv6/NEMO. It expands the scope of network monitoring to mobile devices and networks, and also demonstrates new areas of management e.g. *location management*, in which network monitoring can be applied.

In this paper evaluation is done with a small experimental network, to validate the effectiveness of our idea of location-awareness and the intelligent monitoring traffic. As a future work, we would like to apply our scheme in real environment as discussed in Section 2.3.

Acknowledgments

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