Dynamic Selection of Candidate Device for the Seamless Service
Using User Location Prediction

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Abstract In ubiquitous environment, there are no limits to utilize networks whenever and wherever you are. That pervasive networks are combined with the information devices and then create various services such as car navigation of LBS(location based service) and DMB(Digital Multimedia Broadcasting). As these kinds of services are getting more various, the complexity is also getting higher and ultimately the convergence will make people feel frustrated. One of the solutions is Context-Awareness[1] technology. User interface with context-awareness filters unnecessary information and prevents users from being blocked due to the massive information. In this paper, we describe the seamless service system based on location-awareness, which is a type of context-awareness. We developed the system based on UPnP AV Framework. This system provides the automatic terminal device selection for the nomadic user. The system establishes new connections for the ongoing streaming playback session with the new AV devices without substantial loss of playback so that the user can enjoy the seamless service. The AV device selection based on the user's location needs no user's intervention or notification so it achieves the improvement of usability and complexity.

Keywords: Location-Awareness, Service Mobility, Indoor Location Sensing, Session Mobility, UPnP

1. Introduction

There is a wide spread range of terminal devices and people often carry more than one. Each device has been developed for some special purpose. However, recently the device convergence appears and the device is being developed to have multiple purposes and functionality. The multi-purpose device generally has high portability and system complexity. In addition to the device convergence, network environment is evolving to pervasive network so fast. This evolution opens ubiquitous computing era. In ubiquitous computing environment, people use their converged devices, and these devices access networks and provide lots of information and services. Sometimes the information and services seem to be bothersome and unwelcome because these information and services are unnecessary or even useless under some specific user context.

In other word, people utilize the information and service differently according to their context in ubiquitous environment. Therefore terminal devices are not only combined with various functions and services but also should be able to understand current context or situation. That is, each device needs to have context-awareness. The context-aware device can interpret and deal with information and services correctly according to the user context. However that is considered only within single device boundary. From the point of view of people, they expect to be satisfied with the service at any time and with any device around them. In order to satisfy them, terminal devices primarily have to guarantee the seamless service. Undoubtedly user context and desire are changeable at every moment so that it isn' t easy to provide the seamless service. Therefore, devices should predict the change of context and desire, and prepare for them. Devices essentially share their properties and status with one another and utilize this information to support the seamless services.

In this paper, we explain about selecting terminal devices for the seamless service by predicting the next terminal device. With location sensing technique based Bluetooth, which is widely deployed and also very easy to be used, as a user is moving, the nearest device is selected for the service. The seamless service is also provided. We have developed the system which provides terminal device change and session mobility, and thus supports the seamless service on the context-aware home entertainment system. Each device comprising the system collaborates with one another to locate the nearest or the most proper device to play multimedia contents whilst the user is on the move.

The rest of this paper is structured by follows: in the next section, we explain serveral related works. In Section 3 we discuss our location-awareness algorithm and device collaboration for seamless services. We briefly describe the architecture of the context-aware home entertainment system, u-MESSAGE(ubiquitous MEdia Stream Switcher At Genius Entertainment), and implementation of each component in Section 4. Finally, we present our conclusions in Section 5.

2. Related Works

To support the seamless service, it is essential that user locations should be aware and related information should be migrated quickly. Firstly examining about location-awareness, wireless technology remarkably has been developed to provide location-awareness for last decade. The main purpose of this technology is for remote communication. It is also used for location positioning. For example, Global Positioning System (GPS) provides location information obtained by a group of orbiting satellites. GPS can give user locations very accurately but its signal is easily blocked and absorbed by walls or some obstacles so it is not suitable for indoor environments.

Fortunately, the recent advances in indoor location positioning technology are able to locate objects. Under a more controlled environment, several systems based on location-awareness have been developed: MS RADAR [2], SpotON [3], BIPS [4], etc.

RADAR is a 2.4GHz license-free ISM band RF based system for locating and tracking users inside buildings. It is composed of multiple base stations and one mobile host. Each base station records tuples of the form (t, bs, ss), respectively timestamp, base station and signal strength. The mobile host records tuples of the (t, x, y, d), respectively timestamp, x and y of user location, and direction (one of north, south, east or west). This information is collected at least 20 times during the off-line phase and then unified as a single table containing tuples of the form (x, y, d, ss, snr). During the real-time phase, a data of the form (t, bs, ss) is collected and RADAR searches through the table. To reduce the significant effort of the off-line phase, RADAR suggests signal propagation model, which generates a set of theoretically-computed signal strength data using Floor Attenuation Factor propagation model suggested by Seidel et al[6]. RADAR is simple yet effective signal propagation model. But the resolution of the RADAR system is in the range of 2 to 3 meters and this is not suitable for comparatively a small space.

SpotON has suggested a new tagging technology for three dimensional location sensing based on radio signal strength analysis. In SpotON approach, objects are located by homogenous sensor nodes without central control. Each node has a special hardware that will serve as object location tags. This hardware emits and receives radio signal strength information and uses it for estimating inter-tag distance. Using this hardware, SpotON is possible to support sub 1 meter location sensing accuracy. However, a complete system has not been made available as of yet.

Bluetooth Indoor Positioning System (BIPS) uses Bluetooth technology for an indoor positioning service designed to track mobile users. Contrary to other systems as mentioned above, BIPS needs no additional sensors to detect mobile nodes because BIPS builds ad-hoc network between mobile parts and static parts of the system and notify presence or absence of mobile nodes. The static parts of BIPS are a locally distributed system consisting of a centralized server and a set of workstations interconnected via an Ethernet LAN. Every workstation is provided with a Bluetooth interface that is able to communicate with mobile devices. These workstations discover mobile nodes that enter the coverage area of the workstations and tell their locations to the central server. The location information is stored in a database for the sake of successive lookups. BIPS is a little bit inaccurate for position information. However BIPS does not impose very stringent requirement on position information maintenance, which means a good tradeoff between the computational load and the precision in representing position information. As a result of this, BIPS provides location information about moving users with room level accuracy. In an extended space, it is not suitable.

Another related idea is about information migration for the seamless service. Information migration on u-MESSAGE system is much related to session mobility. Therefore, next related works we examine are the latest developed systems which support session mobility: ENME [5], u-MOST [6], etc.

ENME provides SIP based session mobility. It manages communication session based on user context. ENME has four basic entities: USER, Zone, Device, and Session. User entity is an entity for a person accessing to use the offered application. Zone entity represents a geographical area where a user and a device are located inside. Device entity describes a publicly available terminal and it capability. Last entity Session represents a communication between two or more parties using SIP [7] and its extension. ENME uses RFID for sensing user movements. Therefore if RFID reader recognizes user movements, ENME checks for available devices and moves the ongoing session to the new device. In order to implement this logic, ENME follows these steps. Firstly the Context Handler which checks user movements is using a SIP Interface in order to send and receive SIP messages. When the Context Handler is notified that a user has moved to another zone, and if a new device is found, it sends a CCRequest to the current terminal in order to notify it of the newly available high capability device. For the ENME application the receiver initiates a REFER message to its corresponding communication partner. After that the message flow is according REFER RFC, and the media flow is now established with the new device.

u-MOST is a streaming server system based MPEG-21 DIA (Digital Item Adaptation). It provides a mechanism to select a proper content's resource adapted to the user's environment statically. Furthermore, the streaming system includes on-the fly transcoding mechanism to endure a serious congestion. u-MOST supports session mobility using RFID. If a user using content moves to another zone, DB system stores some information about the user and session. When the user enters a new zone, RFID reader asks the user to DB system and recreate that session with s new device in that zone.

All systems for indoor location positioning are comparatively quite accurate but they need extra devices. u-MESSAGE system uses our empirical method for system efficiency rather than adopts one of these methods. Our system also supports session mobility, and for the sake of the seamless service, all devices involved in the system share their properties and status.

3. Dynamic Device Selection Algorithm

In this section, we explain how the system locates the user by Bluetooth and how the system selects the next terminal device for the seamless service using prediction of user location.

3.1 Location-Awareness Algorithm

In order to select the next terminal device, u-MESSAGE system has to know which device is the nearest one so that people can use the nearest device as their locations are changed. To find the nearest device can be done by radio signal strength of Bluetooth. We have collected signal strength Bluetooth devices emitted and figured out its validity even if we consider the effects of absorbing and diffusing the radio signal. However, we have a critical problem. Signal strength is too various at one location so that we can't use that value directly. Therefore, we use this empirical formula to reduce the deviation.

$$ESS(k+1) = (1 - \alpha)SS(k+1) + \sum \alpha^{k-i+1}(1 - \alpha)SS(i)$$

SS and ESS mean signal strength and estimated signal strength respectively. SS(k) and ESS(k) mean the k-th observed data and estimated data where k=1, 2, 3,.., n. The index of the summation is i and the limits of the summation are the bigger one from 1 or k 9, and till k. α is the weight value between 0 and 1. The formula is composed of the last signal strength and the average of 10 recent signal strengths.

In addition, we reduce the effects of signal variation by adopting a state machine. This state machine decides whether change to a new terminal device should be necessary or not. Only the case that one device is selected three consecutive times as the nearest one changes to a new terminal device. Figure 1 shows the flow of terminal device change.

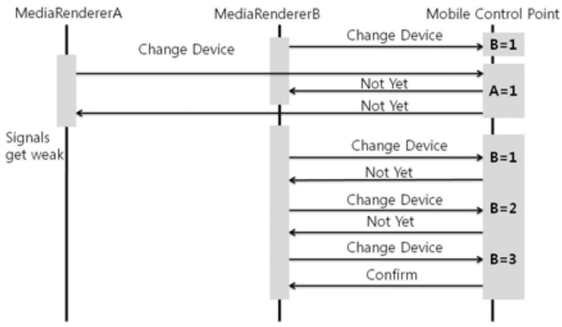

Figure 1 Flow to change terminal device

3.2 User Location Prediction

User location prediction is essential for the seamless service because some information for terminal device change should migrate to the new device. This migration takes lots of time and has a bad effect on the seamless service and this information thus migrates to new terminal device in advance. For example, figure 2 depicts some devices and interaction to predict the next terminal device in UPnP[8] network. MS, MR, and MCP are MediaServer[8], MediaRenderer[8] and Mobile Control Point[9] respectively. The user is carrying MCP and the other devices sense the signals MCP emitted. The other devices infer the location by the signals they received. If the user plays some contents with MR1 and then moves toward MR2 or MR3, for the sake of seamless service, the terminal device MR1 should pass the session and control information to MR2 or MR3.

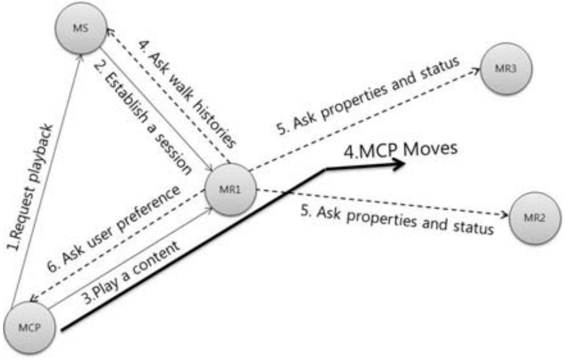

Figure 2 User Location Prediction Flow

In order to pass this information, MR1 has to predict which MediaRenderer is going to be used. To make a decision, MR1 needs to consider the current user context and thus asks MS, MCP, and two MR devices some related information: walk history, user preference, device properties and status. The walk history holds a set of records about the path the user walked before. It contains a random sequence of MediaRenderers. MR1 primarily considers this information as the base of prediction. MR1 passes the current walk path and then MS searches the history record which contains that pattern. However if MS finds out that, MR1 doesn't follow that result because we consider the probability of opposite case. Therefore we assume the result has the normal distribution. MR1 selects one of both considering the probability.

In addition to the probability of the walk history, the property and status each MediaRenderer has and the user preference on MCP are considered. The property is the capability or attribute of MediaRenderer such as display size, resolution, CPU, memory, network bandwidth, codec, etc. The status is the current situation of MediaRenderer such as CPU and memory usage, network availability, etc. MediaRenderer shares this information by XML document file. Figure 3 shows the XML schema for the property and status.

Figure 3 The schema for properties and status

```
  <xs:element name="device" type="DeviceType" />
- <xs:complexType name="DeviceType">
  - <xs:sequence>
      <xs:element name="property" type="PropertyType" />
      <xs:element name="status" type="StatusType" />
      <xs:element name="name" type="string" />
      <xs:element name="IP" type="string" />
    </xs:sequence>
  </xs:complexType>
- <xs:complexType name="PropertyType">
  - <xs:sequence>
      <xs:element name="name" type="string" />
      <xs:element name="value" type="string" />
    </xs:sequence>
  </xs:complexType>
- <xs:complexType name="StatusType">
  - <xs:sequence>
      <xs:element name="cpu" type="xsd:positiveInteger" />
      <xs:element name="memory" type="xsd:positiveInteger" />
      <xs:element name="network" type="xsd:positiveInteger" />
    </xs:sequence>
  </xs:complexType>
```

The user makes a decision for terminal device selection in advance. User preference is represented by the priority of device. MCP provides the interface to set user preference. This information is stored at MCP and whenever MR asks, MCP gives that as XML document.

Using all of this information, MR1 selects one device as the candidate. First MR1 predicts the candidate device by the walk histories, and then decides the direction. After the decision, MR1 searches the preference but if the preference is not suitable for the current content, MR1 tries to find the suitable device for the content using the properties and status.

4. System Development

In this section, we explain how we apply our location-awareness and device prediction algorithm to the u-MUSE System[10]. This system is named as u-MESSAGE System. First we describe the architecture of the system, and then provide results of execution.

4.1 System Architecture

u-MESSAGE is an extended home entertainment system based on UPnP. Our system provides the play-back service without detail knowledge or information about devices, media format, protocol, etc. In addition, while a user is walking, the system discovers adjacent devices and selects the most available one of them at that time. Using this location-awareness functionality, the user can continue to enjoy the playback service. Figure 4 shows the system architecture. u-MESSAGE system are composed of different kinds of device, database, and network peripherals: MediaServer, MediaRenderer, Mobile Control Point, access pointer, hub, etc.

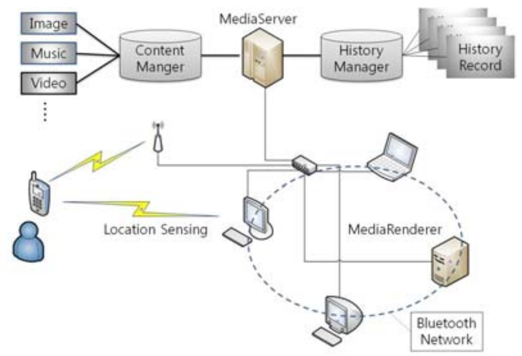

Figure 4 System Architecture

First, a user using Mobile Control Point detects MediaServers and MediaRenderers. MediaServer manages their contents by Content Manager and provides the content list to Mobile Control Point. MediaRenderer also gives some information about their capabilities. After receiving information, Mobile Control Point selects content from the list and asks MediaServer to play the content at one MediaRenderer. MediaServer negotiates with MediaRenderer to make a connection and if that' s successfully done, the user enjoys the content through the MediaRenderer.

At this moment, if the user moves toward other MediaRenderers, The MediaRenderer recognizes that MCP is getting away from it because MCP' s Bluetooth signals gets weaker. From this, the device selection algorithm starts. First, MediaRenderer has to decide what device is the candidate device. Therefore MediaRenderer asks MediaServer the walk histories. MediaServer stores all walk histories at its local database and uses it for searching the patterns MediaRenderer asked. If it finds, it sends the result to MediaRenderer as a XML document. MediaRenderer also asks its adjacent devices their properties and status, and asks Mobile Control Point user preferences. MediaRenderer considers all information and finally decides which one is the next. MediaRenderer thus passes the session information, the current walk history, and content information and then notifies MediaServer and Mobile Control Point that the next terminal device is determined.

4.2 Device Implementation

u-MESSAGE system comprises of MediaServer, MediaRenderer, Mobile Control Point, and some database and network peripherals. Basically all devices communicate on IP based-networks. However, terminal devices, Mobile Control Point and MediaRender, also communicate on Bluetooth ad-hoc network for location-awareness and sharing their properties and status.

Mobile Control Point is the device which people carry. It detects MediaServer and MediaRenderer, and controls them remotely. It' s also able to control the flow of playbacks. Besides, Mobile Control Point has Bluetooth communication ability so that it emits radio signals. Its signals are used to infer the user location by MediaRenderers. Figure 5 shows the architecture of Mobile Control Point.

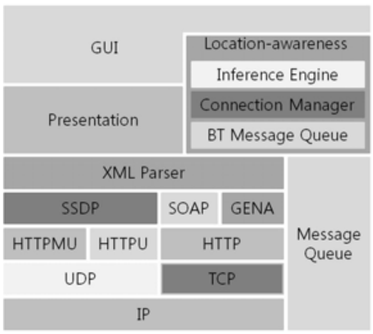

Figure 5 Architecture of Mobile Control Point

We have developed Mobile Control Point on Windows Mobile 5. We use MFC for GUI layer and presentation layer and C/C++ for the others. Especially, we use WIDCOMM SDK for location-awareness and ad-hoc network.

MediaRenderer provides the interface to control its attributes and to play contents. If the user starts to move to another place, MediaRender decides what device is the next terminal device. MediaServer tells a device ID as a hopeful to MediaRenderer. For final decision, MediaRender additionally asks its adjacent MediaRenderers their properties and status to find the most suitable device at that time. The properties and status are transferred by Bluetooth ad-hoc network. We use WIDCOMM SDK for Bluetooth communication.

MediaServer contains multimedia contents and the walk histories. It provides the content streaming service or the pattern match service. MediaService records the current sequence of MediaRender and passes this history to History Manager when Mobile Control Point is out of network. When MediaRenderer asks the walk histories, History Manager compares the current sequence with its walk histories. All histories are stored in the xml document and thus History Manager searches the sequence using DOM API.

We integrated all components into u-MESSAGE system and launched it. We used three desktops and a PDA. All three desktops have a Pentium 4 process and 1G memory. We have experimented with u-MESSAGE system in 8.5m x 5.8m room. Figure 6 shows snapshots of the execution.

Figure 6 Execution of u-MESSAGE system

5. Conclusions

In this paper, we have presented our location-awareness and dynamic device selection, and explained u-MESSAGE system. Our location-awareness algorithm is based on signal strength. To locate users, we use the recently observed 10 signal strength data and the last signal strength data. Therefore if this estimated value becomes lower than other devices, dynamic device selection starts. Although the next candidate device is determined successfully, in order to support the seamless service all devices in network share their properties and status and some historical information. With this information, MediaRenderer predicts the next terminal device and passes all information about the ongoing streaming session. Therefore, the next terminal device can play the session seamlessly.

In the future we will refine our prediction algorithm by adjusting each factor and improving performance. Moreover, we are going to add noise to our probability function. Therefore, u-MESSAGE system gets better performance and prediction accuracy under the real world condition, and supports the seamless services.

Acknowledgement

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