Agent Based Device Adaptability in Ubiquitous Environment

Swapnil S. Ninawe and Pallapa Venkataram

***Abstract*—The proliferation of wireless technologies along with "anytime/anywhere" paradigm requires new scenarios for service provisioning. A user is often surrounded by different mobile devices, are often equipped with different network interfaces, which might be of different access technologies. The user tend to switch devices based on his requirement, hence switching of devices depending upon the content, capabilities of devices and context of the user are to be taken into consideration. The content to be provided must be compatible with the user device while capabilities of the device are to be monitored according to the application requirements, and network connections should be placed on the best possible interface based on these requirements along with context of the user. In this paper, we present an Agent based Device Adaptability in Ubiquitous Environment (ADAUbiE) which takes content, resources of device and context of the user into consideration to carry out device adaptability.**

***Index Terms*—Content, context, device adaptability, resources, ubiquitous computing, wireless networks.**

I. Introduction

Ubiquitous computing tends to impact on everyday life of users profoundly. It opens new era in the paradigm of computing where users can acquire services “anytime/anywhere” [1], and provides a method to enhance computer usage by making many computers available in the environment, but making them effectively invisible to users. Salient features of ubiquitous computing includes zero administration, context awareness, interoperability, mobility, seamless connectivity, etc., one of them is device adaptability which is the most distinguishable. Device adaptability is a cornerstone in ubiquitous computing environment which provides assurance for change of devices, i.e., gives freedom to users to access application on any device, unlike in traditional networks which is neither context sensitive nor unobtrusive to users. The purpose of device adaptability is to provide services with omnipresent and exceeding limits in all the devices to which users are surrounded enabling high mobility, application continuity and convenience to users. Device adaptability makes users device independent (especially when accessing various devices from various places), and maintains continuity of application on different devices like laptop, PDA, desktop PC, Smartphone, etc.

Ubiquitous computing unfolds new dimension to the everyday life of users who are often surrounded by number of devices like Smartphone, laptop, desktop PC, printers, etc. which come up with many network interfaces. For example, laptop comes with Wi-Fi as well as Bluetooth interfaces, printer comes with Bluetooth interface. A small scenario could be a user moving from home to the office; where at home he could use desktop PC or HDTV, and smartphone while travelling to the office. After the user reaches to the office, he could use laptop. Switching of devices and networks can be described by above scenario where at home, desktop PC over wired network was preferred. While travelling, Smartphone over UMTS network was preferred, and laptop over Wi-Fi network in the office was preferred. These requirements make device adaptability in ubiquitous environment difficult for user to (i) move freely among homogeneous as well as heterogeneous networks and (ii) change devices while maintaining application continuity [2].

In an environment where context [3] changes (due to mobility of the user), requirements for current running application may change which needs to compensate for adapting the application or network environment or context of user or combination of these. Thus, switching of devices in homogeneous as well as heterogeneous network along with the user imposes a major task. The selection of devices depends on factors like network resources, devices resources, context of the user, user preferences, etc., opening new challenges for service provisioning [4].

A. Proposed Idea

In this paper we propose an agent based solution for device adaptability in ubiquitous environment. The method involves central ubiquitous system which runs static cognitive agent (SCA) and has inputs from servers and databases. When the user device enters in ubiquitous environment, SCA tries to identify it. In case when the user moves out of reach of the SCA, mobile cognitive agent (MCA) is created and deployed by the SCA, which can carry out switching of the device. MCA also interacts with the local administrator to make sure necessary actions for device adaptability are to be carried out, and provides continuation of the application.

B. Organization of the Paper

The organization of the rest of the paper is as follows. Section II covers related works on device adaptability. Some of the definitions and examples of device adaptability are outlined in Section III followed by the architecture and the system model of an Agent based Device Adaptability in Ubiquitous Environment (ADAUbiE) in Section IV. Working of device adaptability based on content, resources of device and context of the user is discussed in Section V. Algorithms developed for three cases are shown in Section VI followed by generic working of device adaptability in ubiquitous environment using the ADAUbiE system in Section VII. Case

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study, simulation environment, simulation results and conclusion are covered in Section VIII, Section IX, Section X and Section XI, respectively. The results acquired are quite encouraging for uninterrupted application continuation to the user in a ubiquitous environment.

II. Related Works

Very few research works are available on change of the devices in traditional networks but not in the case of ubiquitous networks which consists of homogeneous as well as heterogeneous networks. The Xadaptor was considered in [5] where integrated adaptation mechanisms for various content types was performed and organized them into rule based techniques but fails to consider adaptation for change of devices. The proxy based architectural framework where services were available for content adaptation, a graph based content adaptation algorithms were developed in [6] for distributed computing environment. Services oriented Context-Aware Middleware (SOCAM) architecture for rapid prototyping of context-aware mobile services along with policy based approach which fascinated end users services context awareness and by triggering actions of predefined policies in response to satisfy context sensitive conditions were considered in [7] for mobile computing environment. The criteria for reflecting relevant characteristics of wireless and mobile access networks such as WLAN, UMTS and GPRS were established and judged based on groups, performance, cost and accessibility along with decision making process and its outcome in different situations.

A general framework for multimedia document processing [8], adaptable and extensible context ontology for context-aware computing infrastructures [9] and a tool for declaratively describing the semantics of adaptation services [10] were proposed to carry out adaptation in distinct computing environments. The efficient handoff process in next generation heterogeneous wireless networks and algorithms which offers end user maximum available bandwidth during VHO whose performance differs under different network conditions were developed in [11] for conventional network environment. A mobile agent based framework to carry out functions of geolocation and resource management, flexible automation system and context aware applications were developed in [12] for next generation networking environment.

III. Definitions

In this section we provide brief description for terminologies used in this paper.

A. Device Adaptability

Device adaptability is defined as change of the devices in accordance with the user. The user can switch devices according to his convenience without interrupting continuity of the application.

B. Cognitive Agents (CA)

Cognitive agents are intelligent agents defined as software artifacts that exhibit intelligent behavior in complex domain. The agent can function continuously and autonomously which can carry out activities in an intelligent manner. Agent is responsive to the changes in the environment, and also communicates and cooperates with other agents. CA enables construction of the application with context sensing, adaptive reasoning and responsiveness to the situations in real time.

C. Static Cognitive Agent (SCA)

SCA is responsible for carrying out device change along with network, taking context of the user into account.

D. Mobile Cognitive Agent (MCA)

MCA is created by the SCA which can migrate from one coverage zone to another. The deployed MCA works on behalf of the SCA in new coverage zone (subnet) which is out of reach of the SCA. The functioning and characteristics of MCA is same as SCA except its ability to move which is not present with the SCA.

IV. Proposed Method for Device Adaptability in Ubiquitous Environment

In this section we discuss an Agent based Device Adaptability in Ubiquitous Environment (ADAUbiE) which centrally runs programs where the ubiquitous application is initiated. The ADAUbiE runs as supporting system to the ubiquitous application and initially gathers information about the devices and type of contents used in the application of the user. Based on the circumstances such as change in content type, low battery power, low network bandwidth, user preferences and location, etc., the system adapts itself to the required devices and continues application without fail.

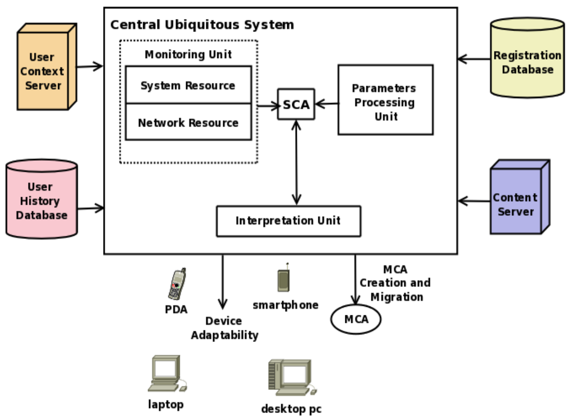

Fig. 1. The ADAUbiE architecture.

The change of device and network taking context of user into account are the key factors in proposing device adaptability in ubiquitous environment. We discuss functioning of the proposed ADAUbiE architecture (shown in Fig. 1) in detail component wise as follows. The main component of the architecture is the central ubiquitous system which has inputs from various servers, databases and devices. The user context server provides location, activity, status and behavior parameters of the user. The user history database consists of parameters like past interaction with the device, movement pattern, etc., while the registration database contains device information regarding identity of the user device. The content server contains various formats of the same content, for example, high definition (HD) video on laptop can be shown in 3GP format on Smartphone. This is due to the fact that Smartphone cannot process HD contents.

TABLE I: MONITORING UNIT

Component	Parameter	Description
(1) Device Capabilities	CPU Load	Average load on the system
	Memory	Amount of memory required
	Battery	Amount of energy required
	Interfaces	Touch screen, Keypad
(2) Network Resources	Bandwidth	Bandwidth required for application
	Delays	Delays in successive packets
	Received Packets	Sequence of packets received in real time

The functioning of the central ubiquitous system in coordination with the SCA can be divided into three units.

1) Monitoring unit

It is responsible for monitoring device capabilities and network resources. The parameters and their functions are described in Table I.

2) Parameter processing unit

This unit collects parameters brought from the user context server, history database, registration database and content servers.

3) Interpretation unit

The data collected from monitoring unit and parameter processing unit are given as input to the interpretation unit which is responsible for adaptive reasoning, and hence its ability to monitor and respond to situations in real time.

SCA is capable of creating MCA, and is able to deploy it to the predicted zone prior to the user movement. When SCA predicts the next zone of the user, an instance of MCA is created. MCA carries user's and the device current status to the predicted zone, and the reservation of the resources is carried out prior to the migration of the user.

The system model of ADAUbiE is shown in Fig. 2, where three zones are shown and zone 1 is covered by the SCA. Consider the user is at home under zone 1 who is watching HD video on laptop, and now wants to move to the office.

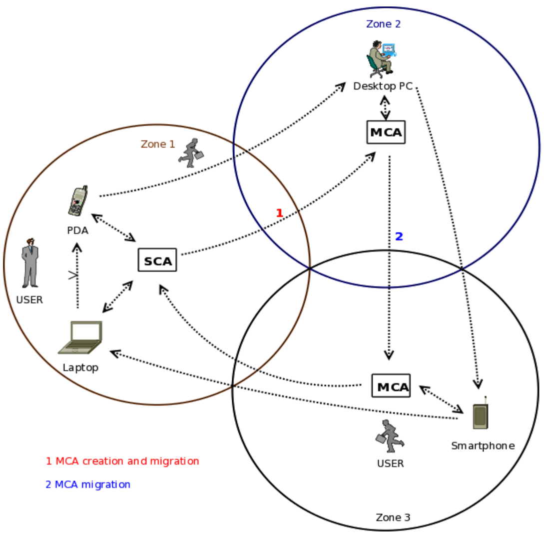

Fig. 2. System model of the ADAUbiE.

Hence he wants to switch the device from laptop to PDA (device change). This action is predicted by SCA in advance and search for the new device starts. If the selected device is not identified, then the device identification is to be carried out. Now, when the user moves out of SCA zone, the movement is predicted by SCA and deploys MCA in the direction of the user movement (here zone 2). MCA acts on behalf of SCA and starts searching for the new device in its zone. Let's say newly selected device is desktop PC, and the application gets continued on it. Consider when the user moves from zone 2 to another zone 3 which is out of the reach of the MCA. MCA predicts the user movement and gets migrated along with the user to the new zone 3, and it starts searching for the new device (here Smartphone). In case of contents not suitable for newly selected device, content transcoding is to be carried. When the user moves back to the SCA zone, MCA migrates along with the user to the zone 1 and transfers parameters to the SCA.

V. WORKING OF THE ADAUBIE IN THREE CASES

In this section, the working of ADAUbiE based on content, resources and user context is discussed.

A. Content Based Device Adaptation in the ADAUbiE

In this case, variation of content is considered to carry out device adaptation, where we have considered PDA over UMTS connection. When high quality contents are detected (say sudden appearance of bitmap image or XviD video format) the device cannot process such content. Hence, CA performs content adaptation, and sends the information to the device. Working of this case is shown in Fig 3.

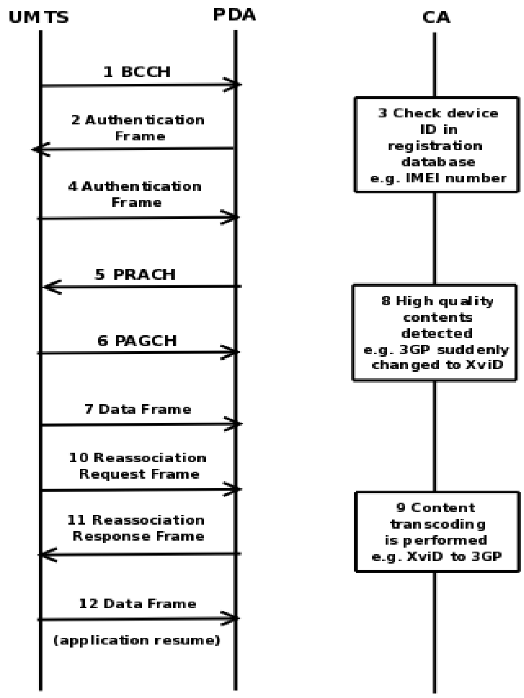

Fig. 3. Content based device adaptation in the ADAUbiE.

B. Resource Based Device Adaptation in the ADAUbiE

In this case, capabilities of the device are taken into account for device adaptation. Consider the user who want to access the application on PDA via Wi-Fi network. Initially the device identification followed by acquiring parameters and resource reservation are carried out. Suppose PDA battery is depleting which is informed by setting power management bit to 1. Hence the CA starts searching for the new device in the environment, let it be laptop. After identification, acquiring parameters and resource reservation, the deauthentication frame is sent to PDA. With the help of association frame, the contents of the buffer are diverted to laptop. Stepwise working of the scenario is shown in Fig. 4.

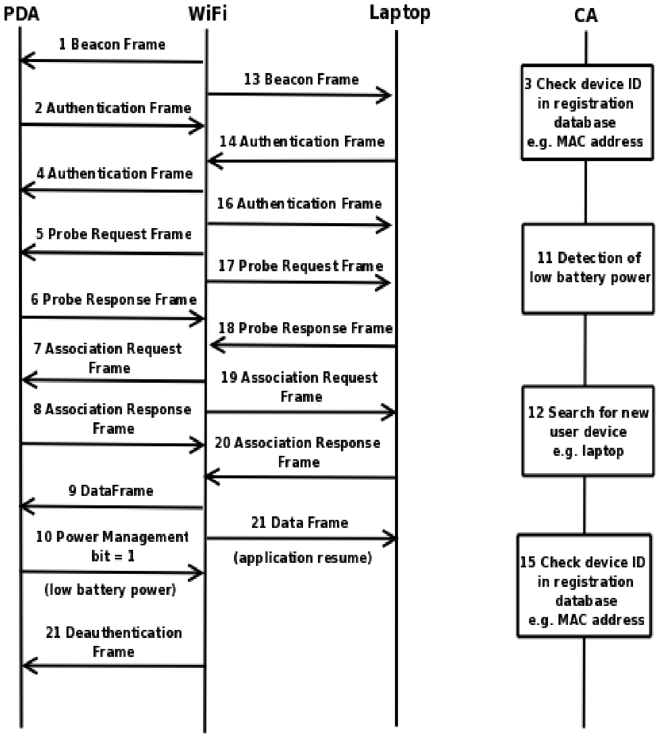

Fig. 4. Resource based device adaptation in the ADAUbiE.

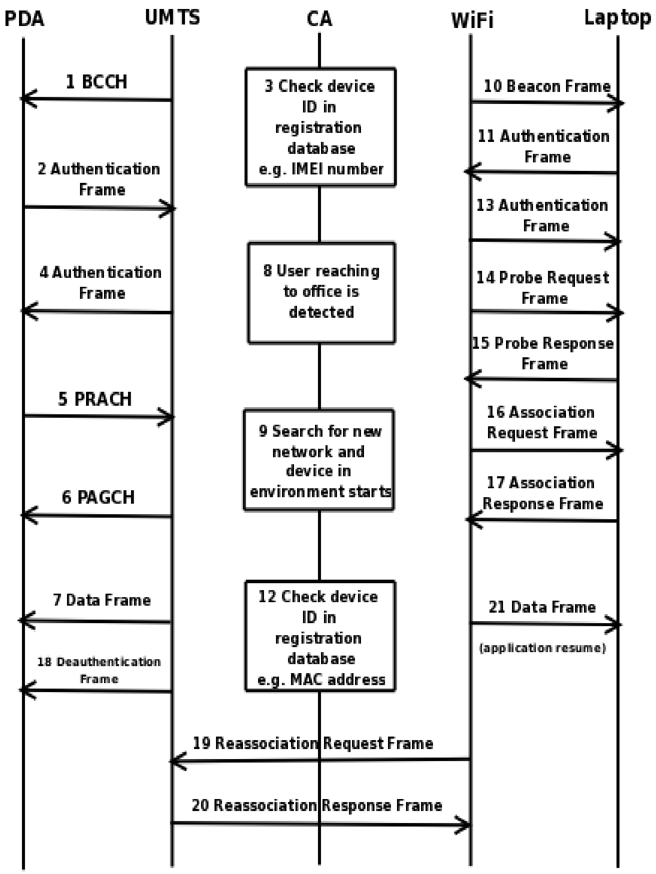

Fig. 5. User context based device adaptation in the ADAUbiE.

C. User Context Based Device Adaptation in the ADAUbiE

In this case, context of the user is taken into consideration for device adaptation. Consider PDA with UMTS interface and laptop with Wi-Fi interface. When the user reaches the office, CA detects it, and searches for the new network and devices in the environment. After identification, acquiring parameters and resource reservation, deauthentication frame is sent by CA to divert contents of UMTS to Wi-Fi. Working of this case is shown in Fig. 5.

VI. ALGORITHMS

In this section we provide algorithms for content, resource and user context based device adaptation in the ADAUbiE. The algorithm for content adaptation involves monitoring of parameters of the device and network to render contents accordingly. The change of content is detected by CA followed by content adaptation (Algo. 1). The resource based adaptation concerns with the device parameters especially when the device resources goes down. The low resource (battery power) of the device triggers change of device in the ADAUbiE (Algo. 2). User context based adaptation requires context of the user (location) to be taken into account for switching of devices which initiates device adaptation in the ADAUbiE (Algo. 3).

Algorithm 1 Content based device adaptation in the ADAUbiE

```
Begin
Assume application running on a device over a network
while Not end of the user session do
  Agent monitors parameters of the device and the network
  (like CPU load, memory, battery, bandwidth, delay)
    if Agent detects high quality contents then
      Perform transcoding of contents according to the
      device parameters
    else
    Continue application on the user device
    end if
end while
End
```

Algorithm 2 Resource based device adaptation in the ADAUbiE

```
Begin
Assume application running on a device over a network
while Not end of the user session do
  Agent monitors parameters of the device and the network
  (like CPU load, memory, battery, bandwidth, delay)
    if Agent detects battery power of the device is below
    threshold then
      Agent searches for the new device in the environment
      if User device is active then
        if User device is identified then
          Acquire parameters of the user device
          Provide application continuation
        else
          Search for the new device in the environment
          Send information to the nearest device
        end if
      else
        Find the nearest device to the user
        Send information to the nearest device
      end if
    else
      Continue application on the same user device
    end if
end while
End
```

Algorithm 3 User context based device adaptation in the ADAUbiE

Begin
Assume application running on a device over a network
while Not end of the user session **do**
  Agent monitors parameters of the device and the network (like CPU load, memory, battery, bandwidth, delay)
    if Agent detects change of the user context **then**
      Search for the new device and the network in the
      if Device is compatible with network **then**
        Send information over the new selected network
      else
        Search for the new network in the environment
        Send information to the device
      end if
  else
    Continue application on the user device
  end if
end while
End

VII. Device Adaptability in Ubiquitous Environment using the ADAUbiE

In this section we demonstrate the working of device adaptability in ubiquitous environment using the ADAUbiE system. Device adaptation based on content, resource and context simultaneously compels many challenges in service provisioning. One of such common scenario that can be encountered is as follows. Consider the user watching HD video on his laptop over a Wi-Fi network. Suppose the user starts moving, hence the context of the user (location) changes which is detected by CA. CA starts searching for new device in the environment and let the newly selected device be PDA.

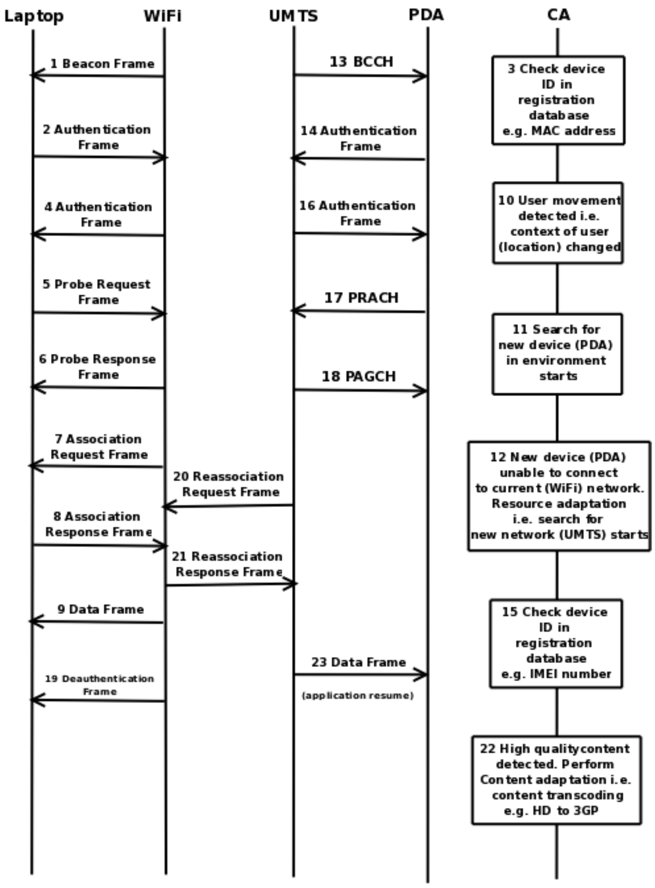

Fig. 6. Device adaptability in ubiquitous environment using the ADAUbiE.

Algorithm 4 Device adaptability in ubiquitous environment using the ADAUbiE system

Begin
Assume application (video) running on a device (Laptop) over a network (WiFi)
while Not end of the user session **do**
  Agent monitors parameters of the device and the network (like CPU load, memory, battery, bandwidth, delay)
  if Agent detects change in the context of the user (location) **then**
    Agent searches for the new device (PDA) in the environment
    if User device (PDA) is active **then**
      if User device (PDA) is identified **then**
        Acquire parameters of the new user device (PDA)
        if Current network (WiFi) is not reachable **then**
          Search for the new network (UMTS)
          if Agent detects high quality content (HD) **then**
            Perform content transcoding according to the device
          else
            Continue application on the device
          end if
        else
          Continue application over the same network (WiFi)
        end if
      else
        Perform registration of the new device
      end if
    else
      Search for the new device in the environment
    end if
  else
    Continue application on the same user device (Laptop)
  end if
end while
End

Since PDA is out of range of Wi-Fi network, the CA starts selection of new network, and let the selected network be UMTS. Since PDA is resource constraint, the content adaptation is to be carried out i.e. HD to 3GP conversion, and the application gets continued on PDA. The working of scenario is shown in Fig. 6 and corresponding algorithm in Algo. 4.

VIII. Working of the Case Study

Working of the proposed system in case of the user moving from one location to another can be seen as follows. Consider the user is at home and running application on laptop which can be video, audio or simple web browsing. To cover most of issues and challenges, we have considered video on demand (VoD) application. Suppose the user who is watching video on laptop, and now it's time to move from home to the office, and later from office to the park. These situations can be completely described by the following cases:

- Case 1: Switching of the device (in SCA)

SCA predicts that the user is about to switch device, and thus starts searching for new device in the environment depending upon parameters discussed in section IV. Let's say new selected device is PDA. The SCA transfers the contents on PDA, and depending upon the device parameters, application gets continued without interruption.

- Case 2: The user moving from home to the office (SCA deploying MCA)

Consider the user moves out of the SCA zone, it is predicted by the SCA. Now, the SCA creates and deploys the MCA in the zone 2. The new device selection gets started by the MCA (here desktop PC), and the application gets continued on the desktop PC.

- Case 3: Migration of MCA

When the user moves out of the MCA zone 2, it is predicted by the MCA. MCA gets migrated to the new zone 3 and starts searching for new device (Smartphone) in the new zone.

- Case 4: Return of MCA to SCA

When the user moves from park to home where the SCA is present, the MCA predicts this movement and migrates to SCA (zone 1). The SCA supersedes the MCA and controls selection of device.

Fig. 7 depicts the sequence of steps that are carried out.

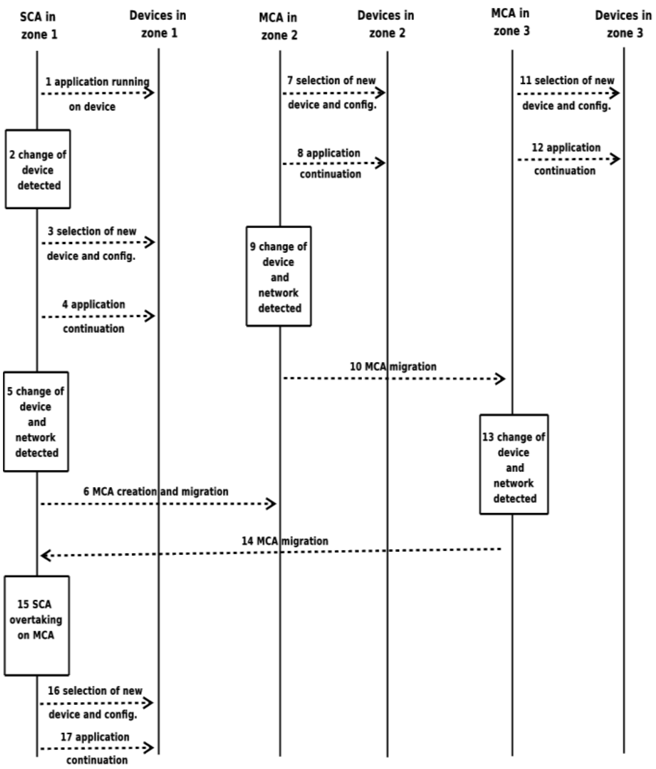

Fig. 7. Working of the case study.

IX. Simulation Environment

We have considered Smartphone with UMTS connection and laptop with Wi-Fi connection. When resource (battery power) of the device gets depleted, it is detected by the SCA (in zone 1) and prediction of the new user device starts (here say laptop is new predicted user device). Parameters of the laptop are acquired, and the content adaptation is carried out. This is due to the fact that laptop with high resources can handle HD video. When the user moves out of reach of the SCA (zone 1), it is predicted by the SCA. The SCA creates the MCA, and deploys it in newly predicted zone. The selection of device and network are performed prior to the switching of the device (see in Fig. 8).

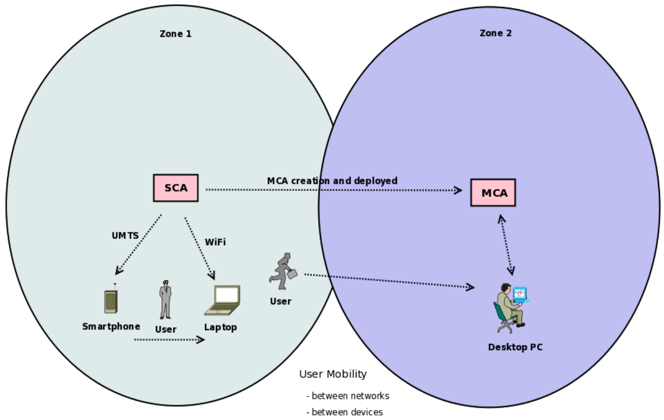

Fig. 8. Simulation environment.

X. Simulation Result

We have simulated content based device adaptability in the ADAUbiE and the result is shown in Fig. 9, where the graph is plotted for fidelity of content against percentage of adapted content. It shows that as more and more content adaptation is carried out, the fidelity of content decreases (diminished up to 37%).

The bar graph in Fig. 10 shows percentage of device adaptability based on resources for various devices. As Smartphone is highly resource constrained, more frequently adaptation is to be carried out as compared to PDA. Laptop and desktop PC have high resources, hence percentage of adaptation is low. Another graph in Fig. 11 shows performance of device against resource of device, where even if Smartphone and PDA have full resources, they can't match in performance with laptop and desktop PC (for Smartphone 69% while for laptop 12%).

Accuracy of device adaptation against user context information is plotted in Fig. 12. Weight based context adaptation is carried out and the result shows that as more and more context information is available, the accuracy of adaptation improves (maximum 84%).

The bar graph shown in Fig. 13 shows percentage of device adaptation against type of adaptation in ubiquitous environment using the ADAUbiE system, and shows that as the user switches from laptop to PDA, the percentage of adaptation is more for content and resource than context adaptation. It is 38% for content, 43% for resource and 19% for context adaptation.

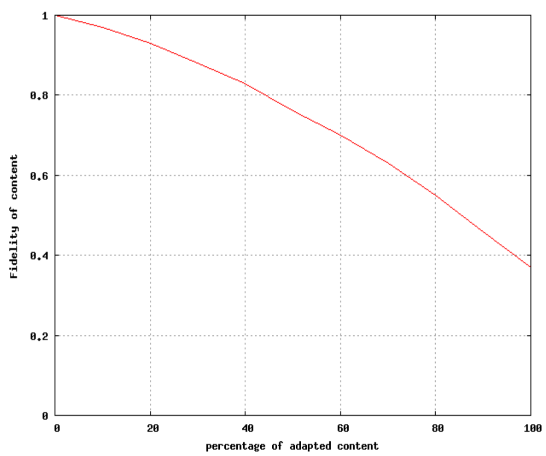

Fig. 9. Fidelity of content vs Percentage of adapted content.

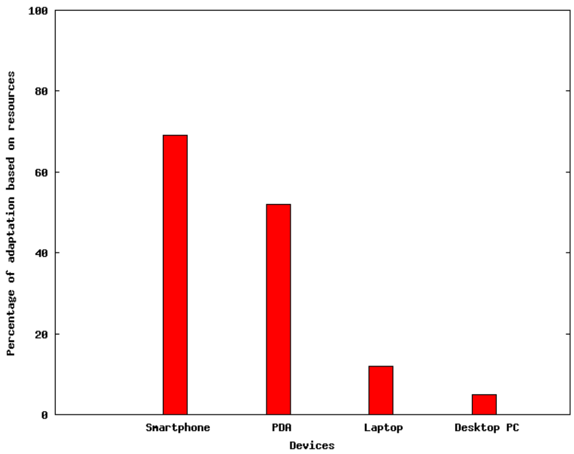

Fig. 10. Percentage of adaptation based on resources vs Devices.

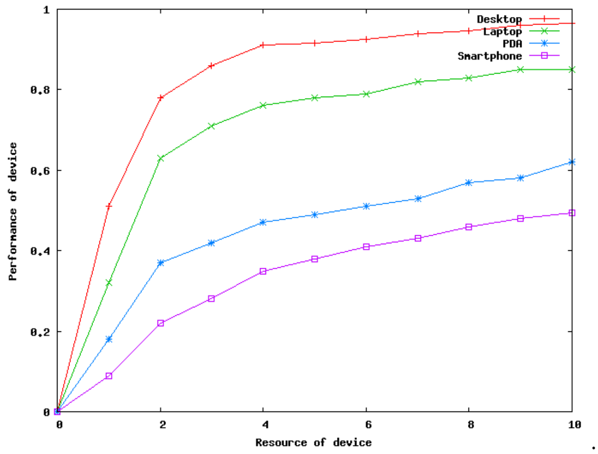

Fig. 11. Performance of device vs Resource of device.

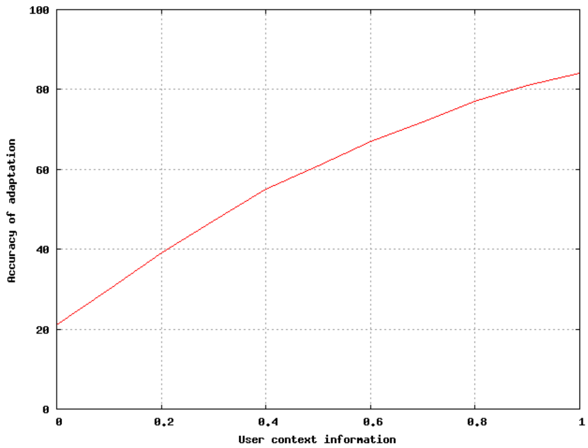

Fig. 12. Accuracy of adaptation vs User context information.

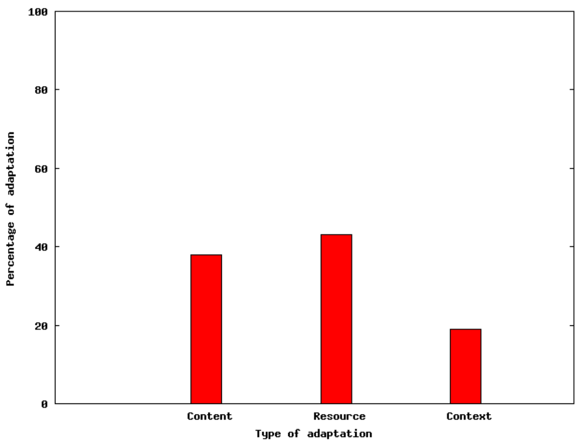

Fig. 13. Percentage of adaptation vs Type of adaptation.

XI. Conclusion

In this paper a new scheme of device adaptability in ubiquitous computing environment using cognitive agent technology is presented. The ADAUbiE provides non intrusive technique of switching of devices taking context of user into consideration. Our cognitive agent based approach provides continuity of application based on content, resources of device and context of user into consideration across various devices and networks. The algorithms discussed can be implemented using agents and can be deployed on any platform in the ubiquitous computing environment. Results obtained are quite encouraging to carry out device adaptability in ubiquitous computing environment.

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