Composite Device Computing Environment: A Framework for Augmenting the PDA Using Surrounding Resources

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Keywords
Personal Digital Assistant (PDA), Handheld Computers, Mobile Computing, Situated Computing, Ubiquitous Computing, Composite Device

INTRODUCTION

The World Wide Web (WWW) continues to enjoy phenomenal growth with the promise of facilitating a digital society. Technology continues to evolve, allowing an increasingly peripatetic society to remain "connected" without any reliance upon wires. As a consequence, mobile computing is a growth area and the focus of much energy. Mobile computing heralds exciting new applications and services for information access, communication and collaboration across a diverse range of environments.

By considering factors such as the user's identity, profile, location, etc., s*ituated computing* is a methodology for imbuing applications and services with more personal and appropriate behavior. However, much current research is concentrated upon the delivery and presentation of context-aware information. Although using different sensing technologies, the Metronaut system [5] and the Cyberguide project [1] use this approach in guiding visitors to locations on a university campus. Location context is also used by the Active Badge System [7] to determine and track people moving around a building.

MOTIVATION

Contemporary wireless solutions typically include PDAs, or notebooks using cellular modems connecting to wireless networks to access a broad array of IP-based services. In the future it is probable that the devices will change; the networks will change; the protocols will change; and content will change.

Typically, popular mobile devices are sized appropriately to fit conveniently into a pocket. Although it is anticipated that the PDA screen resolution and quality will improve, this key social requirement for the device to be pocket-sized therein imposes a constraint upon the maximum physical size of the small screen display. While the other factors listed are likely to evolve, the physical limitation of the display size is likely to remain constant for a longer period.

At Siemens Corporate Research (SCR), our research focus is to provide mobile users with access to rich multimedia information and services. These observations have led us to investigate approaches for overcoming the inherent display limitations of a PDA. In the Composite Device Computing Environment (CDCE) project the surrounding available computing resources are considered as another facet of situated computing. As such a PDA-centric framework has been built to provide a situation-aware mobile information system. Having acknowledged the limitations of the PDA, the CDCE framework provides mechanisms for seamlessly exploiting and interacting with the available surrounding computing resources (e.g., PCs, workstations, TVs, telephones) to augment the PDA. Based upon the user's request, the CDCE framework dynamically creates a unified *composite*, or virtual, device composed of an appropriate mix of the surrounding resources. CDCE flexibly combines the positive aspects of mobility with static computing resources in the vicinity. Hence, the CDCE provides at the user's current location an infrastructure to support a mobile collaborative working environment.

A PDA is used as the primary device through which to requisition information, applications and services. The CDCE framework can offer access to broad range of multimedia services across a multitude of potential output devices. The CDCE framework offers an alternative paradigm for ubiquitous situated computing. The remainder of this paper describes the CDCE framework.

THE COMPOSITE DEVICE COMPUTING ENVIRONMENT

The following medical scenario serves as an illustration of the value of the CDCE framework.

Mobile Healthcare Scenario

In this scenario, the CDCE framework has been deployed within a hospital. Each doctor is equipped with a PDA affording wireless access to the hospital patient information system. When conducting her rounds, the doctor enters the room of the first patient. The doctor wishes to query the patient's medical history, including symptoms, diagnoses, prescriptions and x-rays. The PDA first detects the presence of a TV and a telephone in the room using the infrared interface. The PDA then communicates the doctor's request together with details about the detected devices to the CDCE gateway server. After authorizing the doctor access and verifying a secure connection, the CDCE gateway routes symptoms, diagnoses, and prescriptions directly to the doctor's PDA. As CDCE server is aware of the PDA physical limitations, the x-ray image is transmitted via RF to the TV for viewing. The doctor then uses the infrared capability of his PDA to annotate a region of the x-ray. CDCE then establishes a telephone call to the patient's original doctor for consultation. This arrangement provides a convenient infrastructure for the doctor to access, view, interact and collaborate upon the multimedia information.

This scenario demonstrates the way in which location information is utilized. It demonstrates the use of the PDA as a unique communication and access device. Also, tasks that are not suitable for the PDA to perform are outsourced to more appropriate devices. It illustrates the need for the convergence of wireline and wireless networks to transmit the data as well as to establish a short-range ad-hoc network for device detection. Finally, it stresses the importance of the CDCE gateway to format the information in different ways for the different devices.

The CDCE Framework

The above scenario briefly describes the main components of the CDCE framework. The fundamental idea is to avoid having to use a single PDA to perform all tasks. Instead of tying users to the traditional computing environment, we actively seek to exploit it. This idea is based on the observation that our daily life environment is becoming evermore equipped with electronic and computing hardware. For example, a household with a TV, telephone and PC with Internet connection is becoming commonplace. At the office there is a preponderance of powerful hardware such as workstations, PCs, beamers, printers, high-resolution monitors, etc. All of these devices are potentially available to users of mobile applications and services via CDCE.

The research focus of the CDCE project is to:

- develop scenario specific PDA user interfaces; elicit user requests for mobile applications and services
- dynamically ascertain and reserve the appropriate surrounding computing resources
- collate, process, deliver and display on the appropriate devices(s), either in parallel or in sequence, the requested information
- support multi-modal interaction across the range of available CDCE supported computing resources

A number of desirable design goals for CDCE have been identified:

- Adhere to standard protocols and services where appropriate. The PDA interface is a WWW browser and the user requests are transmitted via HTTP to the CDCE gateway.
- CDCE should not require any proprietary software to be installed on the available computing resources in the surrounding environment. A WWW browser is the only pre-requisite, with additional functionality supported through the browser extension mechanisms.
- CDCE needs to be sufficiently adaptive in order to exploit an ever-changing number and diverse range of available computing resources in the surrounding environment. The CDCE gateway must optimize the presentation of the information and the selection of output devices based on whatever resources are currently available.

From Figure 1 it can be appreciated that the CDCE framework consists of four main elements: the PDA, the CDCE Smart Gateway, the computing resources in the "environment" and the Network Communication Model.

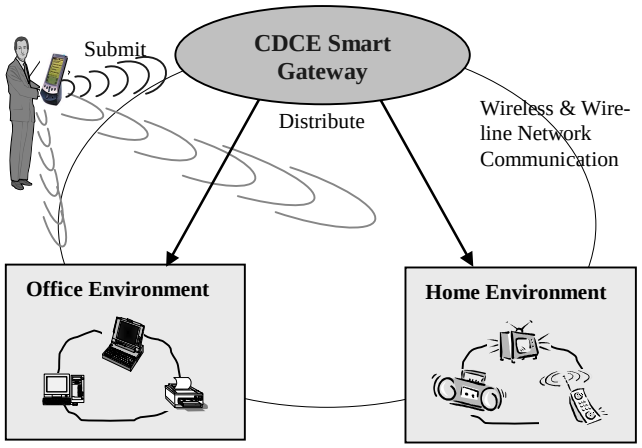

Figure 1: Elements of the CDCE framework.

The PDA detects and reserves available devices in the close vicinity and informs the Smart Gateway. The relatively short existence of the PDA and the continuous introduction of new devices and functionality prevent the definition of standards upon which to rely. Instead, we recognize the initial realization of the CDCE concept requires making

decisions about specific computing platform, such as a wireless IR or RF interface and HTTP/HTML or WAP/WML.

The Gateway intelligently organizes, synchronizes and distributes requested information and services for interactive media access. In detail, it fulfills four major tasks:

- it manages the pool of services available to the users. For example, in the medical scenario it enables specific applications based on the doctor's location, identity and privileges.
- it establishes the composite devices based on location-dependent information received from the PDA, predefined knowledge about the Environment, and dynamic information on the current status of the various nodes comprising the composite device.
- it maps the requests issued by the PDA to the applications, and the corresponding output to the appropriate nodes in the virtual device. In the medical scenario this is manifested by the fact that the Gateway will redirect the x-ray image transmission to the TV via RF.
- it performs the dynamic conversions needed to present the information on the selected output node.

The role of the Network Communication Model is to manage the convergence of wireless and wire line networks, as well as the corresponding communication protocols. This is necessary to ensure a seamless device communication and data transmission. In the medical scenario, the network communications model includes the short-range wireless communication used by the PDA to detect surrounding devices; a cellular or wireless network to support the interaction between the PDA and the Gateway.

Finally, the Environment represents the pool of resources available at the user's current location. These resources can vary considerably from location to location. Figure 1 illustrates two possible environments and the typical range of available resources.

CHALLENGES AND OUTLOOK

Two primary research challenges addressed relate to multimedia information management and the network technologies. These topics are elucidated upon in the following sections.

Information Management and Distribution

A key focus of the research for the CDCE concept is the intelligent information distribution. Hence, the following methods are required to adapt the content to multiple output devices with varying capabilities as well as to the changing number of devices:

- *Splitting*: Intelligent content separation. E.g. a user wants to view a video message in an environment where only a PC without sound card and a telephone exist. In this case the CDCE system would split the audio part and redirect it to the available telephone and the video part to the PC.
- *Conversion*: Media conversion techniques, such as text to speech [2], can be offered when no appropriate devices are available
- *Filtering*: Content extraction and delivery of the sub-content, which can be rendered by the output device. E.g. delivery of only the audio part of the video message to a telephone.

Also important is the smart delivery sequence, or in parallel, of information based on both the number and capabilities of the nodes comprising the composite device.

Mobile User Interface

It is clear that the physical constraints of the screen mean that the information to be rendered on the PDA imposes limitations not experienced on a desktop machine.

Interaction with the environment is crucial and, in view of this requirement, we anticipate three alternative modes:

- *Abdication*: In this case the PDA hands over the control to the device. E.g. once an application is started on PC the mouse and keyboard of this PC will act as input devices.
- *Cooperative*: PDA and input devices of the output device can be used to control the application [4]. E.g. a slideshow can be annotated either using the mouse and keyboard of the output device or through a specialized and simplified user interface for the PDA
- *Exclusive*: The only input device is the PDA. This is especially important for output devices where no input facilities are connected (e.g. a TV)

The cooperative and the exclusive modes require specialized user interfaces on the PDA. The functionality that these interfaces must provide depends strongly on the scenario. For example, in one scenario annotation functionality is needed, whereas in another it may not.

Network Architecture

To facilitate a bi-directional flow between *PDA-Environment-Gateway-Environment* elements a suitable abstraction for the communication was sought. The use of the Distributed Component Object Model (DCOM) [3] helped to fulfill these requirements. Security cannot be ignored in the design of distributed information frameworks. It is clearly not tolerable for one CDCE user to monopolize another user's machine when in use. The CDCE gateway is the *only* entity with privileges for remote process invocation. To schedule in advance the resources required some scheme for reservation is also required.

Sensing/Detection Techniques

For the CDCE Gateway to construct a composite device, the PDA must detect and communicate information

regarding the available resources. As described in the scenario, IR is a technology suitable for the purpose of device detection. Bluetooth [6] is also another such technology under evaluation for optimizing the process of sensing and detection. The CDCE framework makes the detection and utilization of available devices transparent to the user, thus allowing the user to focus on the actual tasks.

CONLUSION

We have presented a new concept of utilizing location information in order to develop a new class of mobile and ubiquitous services and applications.

Currently, we have successfully developed the first CDCE demonstrator for the "Office Environment". Our system consists of a PDA running Windows CE and multiple Windows NT workstations equipped with infrared serial interface adapters. IR is used for short-range detection. The PDA and Smart Gateway communication is realized using HTTP over a Cellular Digital Packet Data (CDCP) network. The Smart Gateway and output client communication is current achieved by using a LAN. In the demo system a user can detect the NT workstations as potential output devices with her PDA and request the Smart Gateway to stream multimedia files to one device and to enable Microsoft Exchange Webmail service on another. Distributed Component Object Model (DCOM) [3] enables the CDCE Gateway to remotely invoke processes, without any requirement for proprietary client code. A WWW browser is the only client pre-requisite, with additional functionality supported through the browser extension mechanisms.

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