UbiCom
Series

TCG Software LP

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UBICOM PROTOTYPES AND SYSTEMS

The emerging field of ubiquitous computing is inspired by the work of different research organizations which initiated different project and developed system prototypes to explore the capabilities and influence of ubiquitous computing in a real world. This paper aims to provide the brief description of different prototypes and systems which will help the researchers for making their own contribution by introducing the new products and systems in the light of old heritage of ubiquitous computing.

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Prototypes and Systems

Introduction

Since 1988, many organizations have been involved in research activities for ubiquitous computing, where the aim is to find the capabilities and impact of UbiCom systems to the real world by designing different prototypes and systems. These prototypes are the baselines for the researcher to improve effectiveness, reliability, efficiency and performance of the systems by analyzing the characteristics, and output response. Components and architectural details of the prototypes provide solid backgrounds to the researchers and help them to introduce new systems with the extended functionality and improvement. Though, there have been enough work done but many issues are still under discussion regarding the security, location sensitivity and scalability of mobile systems involved in ubiquitous computing. These issues can be justified and refined using the previous knowledge of empirical UbiCom prototypes and systems. In this paper, we provide the overview of some of the initial prototypes and systems that have become the baselines for advance research in the field of ubiquitous computing.

PARCTab

PARCTab system is a research prototype developed at Xerox PARC in 1993 [1], following the system support and infrastructure improvement in later years. The PARCTab project serves as a test-bed for ubiquitous computing with the aim to enrich computing environment by emphasizing context sensitivity, casual interaction and the spatial arrangements of the computer [3]. PARCTab consists of a palm size handheld device called personal digital assistant (PDA) which communicates through infrared transceivers and gateways to applications running on different workstations. Network is designed to cover a limited area for building use where each room acts as a separate communication cell. As compared to other PDAs, most PARTAB applications run on other remote hosts which require reliable communication mechanism through infrared connection. The infrastructure provides reliability and uninterrupted connectivity while PARCTab moves from cell to cell [2]. Regardless of the small size screen with low resolution, PARCTab consists of Interactive user interface to allow efficient text entry and option selection.

Design Principles

The goal of ubiquitous computing is to demand less concentration of user while providing them with more features through the casual interaction. Considering the above definition, the PARCTab initiative was based on some fundamental principles and ideas which provided guidelines to drive a user interactive design of a device. Some of the principles included:

- ***Extreme portability.*** The device is designed to be carried or worn at all times, much like a pager. It's size, weight, and features are intended to promote casual, spur of the moment, computing. For example, it has no power switch and instead automatically turns itself on when a person starts interacting and off after a person has finished interacting [1].
- ***Constant connectivity.*** The system assumes the palm-top unit is always connected to the network infrastructure [1].
- ***Location reporting.*** The location of each PARCTAB is always known to system software [1].

In addition to above principles, the goals of the Xerox PARC for the PARCTab project were:

- To design a mobile hardware device, the PARCTab, that enables personal communication [3].
- To design architecture that support mobile computing [3].
- To construct context-sensitive application that exploits this architecture [3].
- To test entire system in an office community of about 40 people acting as both users and developers of mobile applications [3].

In addition, Xerox PARC also set some other goals for hardware to make it more attractive to the users, compatible with the networks and dynamic with the current context. To fulfill these goals, device was made small in size, light weighted and aesthetically pleasing enough to make it every day life accessory for the users.

Initially, the cost of the hardware and infrastructure were limited to certain range in order to deploy more systems with the office premises for testing. Beside the cost limitations, some other factors were limited by the available technology such as device communication bandwidth, display resolution, processor performance and battery capacity.

System Overview

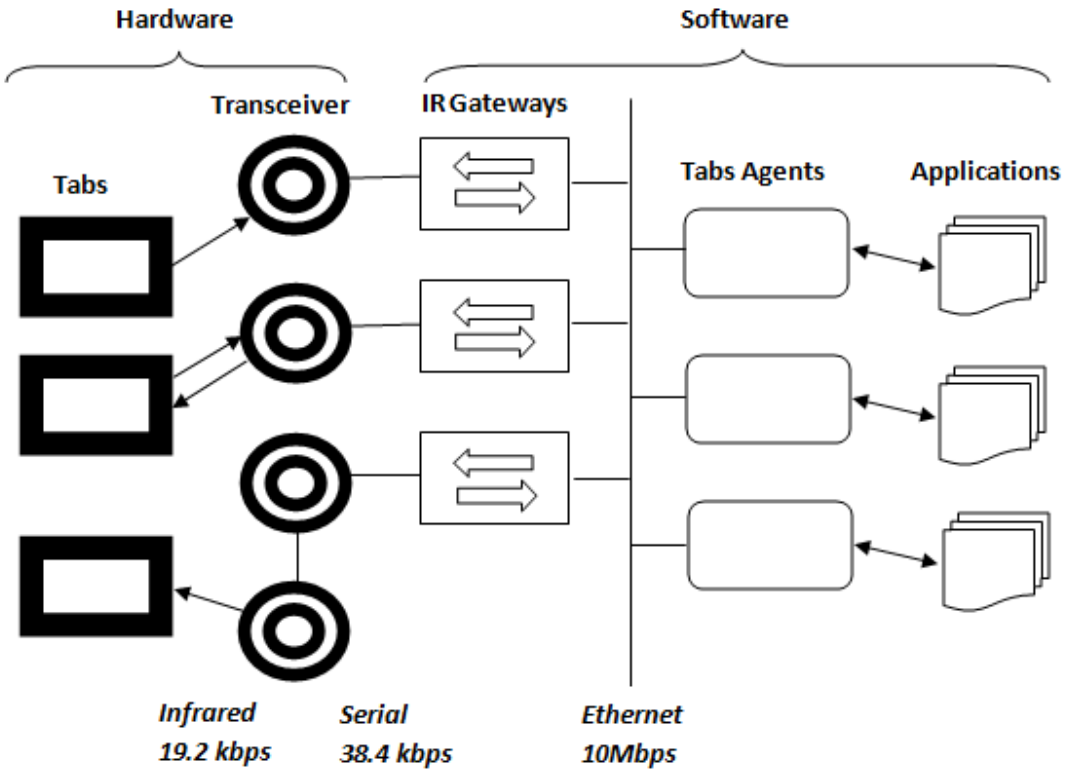

Figure 1: System Components.

PARCTab consists of both hardware and software components along with infrared communication system in order to achieve all design goals. The hardware system components consist of tabs and transceivers as shown in Figure 1. Tabs functions more like a terminal than general purpose computer with limited functionality based on the application software. The advantage of a terminal-based system is a simpler design, less costly production and smaller design [2]. Transceivers are intermediate sensor nodes (base stations) which provide communication channel between mobile tabs and workstation-

based applications as well as between two or more mobile tabs. The Software components include gateways, tab agents and applications. System holds three communication media; infrared connects tab systems with transceivers for message passing, serial lines are used to connect transceivers to workstations hosting IR gateways, and Ethernet provides the connection facility between the IR gateway programs and tab agents. Sun RPC is used for communication among gateways, agents and applications [2]. PARCTab uses simple operating system for tabs with built-in character and icon font sets, and user library for programming tab applications.

System Hardware

PARCTab hardware consists of tabs and transceivers. The engineering decision was made to shape the final appearance and functionality of the PARCTab hardware by considering the limitations and requirements of design which balanced the weight, processor performance, power consumption, communication media and bandwidth, and device structure of the tab.

Mobile Tabs

PARCTab mobile hardware has been designed for use within an office environment. One objective was to create a small and ergonomically design device that can be carried throughout the workday [2].

PARCTab mobile is a small hand held palm device that can fit into a hand easily. The design was made to use with both hands where one hand holds the device and other uses the passive styles or fingers to input commands on touch screen. To convert from right to left handed use, user executes setup commands that rotate the display and touch screen coordinates by 180 degree. However, three ergonomically design buttons were also given at top to make a one hand use of the device. LCD screen of 6.2 cm x 4.5 cm with 128 x 64 pixel screen resolution was chosen to display information. A piezoelectric tone generator provides audio feedback and 1^2C bus connector can be used for expansion [2].

PARCTab contains 12 MHz, 8-bits microcontroller (87C524), an Intel 8051 derivative, to ensure a compact design [3]. Low power feature of the processor helps to increase battery life. Microcontroller also controls the power consumption of display, touch screen, additional RAM and communication electronics of the device.

The rechargeable nickel cadmium batteries are used to provide power to the tabs with the 12 hours continuous use. In practice, while considering the nominal use (10 min/hr, 8 hrs/working day), nickel batteries, with the storage capacity 360 mAh, needs to be recharged only once in a week [3]. Device is also assembled with the power saving feature to ensure that device will be automatically off after a predefined period of activity.

Transceivers

In PARCTab project, Transceiver serves as a communication hub between the tabs and gateways. Normally the distance radius of transceivers' IR communication is 20 ft which can be reduced depending on shorter room area and walls distance. The transceivers hardware performs certain operations including transmission and reception of the signals, verifying checksum, coding and decoding signals, buffering, checking protocol and providing a serial interface to the workstations [3].

Transceivers contain 24 emitters for transmission placed at 15 degree intervals on a circular printed circle board. For reception, two detectors are used that provide total view of 360 degree angle to cover all surrounding area in a particular radius. Transceivers and PARCTabs don't require being at line of sight in order to sense signals for communication, they can sense reflected signals from different surfaces. Normally, one transceiver is used to cover one room with average area. New transceivers can be intelligently placed in a room to cover larger distance without overlapping the area covers by each transceiver.

IR transceivers are capable of sending and receiving signals on multiple data rates and generating link-level acknowledgement packets. Transceivers check the infrared network traffic before sending signal and if network is busy, it waits until congestion is reduced [2].

See the transceiver at: http://sandbox.parc.com/parctab/tspic.html

System Control Software

PARCTab system consists of two different software including IR gateways and tab agents. IR gateway and the tab agents are controlling software that makes the reliable communication possible from the tabs to applications deployed on different hosts.

The IR gateway controls one or more transceivers connected to workstation. It receives data from transceivers connected on serial line and forwards it to the tab agents. In a reverse order, the IR gateway receives data from tab agents, encodes it in IR packets and delivers on an appropriate serial port. The IR gateway uses name service to find a related tab agent by looking on packet's source address. Each IR gateway also holds a long-lived cache of agent network addresses which is used to find the tab agent address that minimizes the use of name service. In addition, the gateway also attaches the return address and a location identifier to every packet sent to tab agent where location identifier describes the location of the transceiver that received the packet. Context sensitive applications can use the identifier in combination with centralized location databases and services to customize their behavior [3]. The IR gateway also performs configurations, error recovery and reporting, and flow control.

The tab agent is a switch board that connects applications with the PARCTab through the IR gateway depending on the location of the tab. Each tab agent operates for exactly one tab and controls communication. The tab agent forwards packets to the tab on getting request from the applications. It

sends packets to application on getting request from the PARCTab including the location identifier that ensures the authoritative source information for the context sensitive applications. The tab agent also manages application communication channels and switches among different IR gateways when tab changes its location. The centralized location service is used to hold the information of tab's known location. Whenever tab agent receives beacon with the different location identifier from the tab, it updates the location service with the latest information and current activity status. The tab agent uses three different statuses: "interactive" when tab is being used, "idle" when agent receives beacon without any event and "missing" if the tab is out of sight [3]. The tab agents handles two types of communication; asynchronous and synchronous. Asynchronous is a one way unreliable communication from tab to applications that includes sequence number to filter out multipath packets received at agent. Synchronous is a two way reliable communication from applications to tab, and a sequence number for filtering retransmission-duplicates at the tab, and match responses to requests at the agent.

The tab agent initially starts a distinguished application, the shell, which is given a capability to connect other applications to the tab. The shell starts all applications and controls which is the foreground application, much like job control under a UNIX shell [2].

Communication Infrastructure

Communication infrastructure for PARCTabs is based on baseband modulated infrared network that connects tab devices with the transceivers placed within a room. Due to the power and cost constraints of the design, infrared is preferred to use over the radio communication system to cover short distance areas. PARCTabs uses 880 nm IR to exploit the small and inexpensive IR components which offer low power consumption with modest communication speeds of 9600 and 19200 baud [3]. Transceivers connect to the tabs through infrared network to listen commands and send variable size packets with maximum length of 256 bytes. A packet broadcast into the infrared band is received by all transceivers within a small room sized "cell" and is copied from the infrared medium by destinations which select it according to the packet's address [2].

Serial connection is further used to connect one or more base station transceivers with the workstation based IR gateways using RS-323 port. The workstation gateway host controls base stations by sending commands over the serial port. Transceivers forward the IR packets to gateways as soon as they are received [2].

Packet Structure

Pkt Type	Length (0-255)	Destination	Source	Data Payload	CS
1	1	4	4	3-247	2

Figure 2: Format of the data fields of link layer packet (Length in bytes)

Data link packets (see Figure 2) used for data sending and receiving are divided into different fields: packet type, length, destination, source, data payload and checksum fields. The packet type field is

always sent as 9600 baud and rest of the packet type fields defines the speed of transmission of the packet which results in variable transmission field for individual packets. The second field contains the length of the packet; usually 14 bytes for uplink and 256 bytes for downlink. The source and destination fields carry the addresses of tabs and transceivers which help to transmit data to the actual destination device. Data payload fields can contain up to 247 bytes of data for transmission. Finally, a 2-byte checksum field is used for error detection and correction [3].

Reliable Transmission

PARCTabs use simple packet-contention access protocols to share medium using time division multiplexing. Data sent from PARCTabs is bundled into packets using baseband modulation of IR channel which further converts packets into sequence of uniform pulses of equal duration (4 μs for each pulse). Gaps between the pulses are usually variables that are used to encode data bits. For locating the carrier band of IR channel, PARCTabs use systematic non-persistent carrier-sense multiple-access protocol (CSMA) that uses a carrier sense and random-exponential back off whenever the channel is busy [3]. IR Transmission creates a strong packet for the local transceiver to avoid collision detection that makes it impossible to detect other packet sent by other device simultaneously. The request bit is used in a packet to request acknowledgement from transceivers to ensure successful data transmission. In case of no acknowledgement, PARCTab keeps on sending packets until feedback is received from transceiver.

PARCTab Applications

The applications for PARCTab systems have been designed by following three characteristics of the system; portability, wireless communication and context sensitivity [3]. The system supports multiple applications running at once, although only one may communicate with the tab at a time. In addition to pen and button events from the tab, applications may receive suspend, resume, and quit events sent from the agent [2].

Several applications have been designed to explore the problems in ubiquitous computing information access, user interfaces for small pen computers, environment control and application migration [2]. Application accessible through the PARCTab system can be categorized into information access, communication, media, computer- supported collaboration, remote control and local operations applications.

Following is a brief description of some of the PARCTab system's applications:

- **Dictionary & Thesaurus.** Allows accessing a large dictionary and thesaurus. It would be difficult to store this amount of information onto a device the size of the tab [2].
- **Calendar.** The calendar application provides a tab interface to Sun's calendar manager program. A user may view and mode appointments while away from their workstation [2].
- **Weather.** The weather application is an example of the tab accessing time dependent information. The program displays the current weather conditions as reported by a rooftop weather station as well as the area forecast obtained from an Internet host [2].

- **Birddog.** A reverse pager application that reports peoples location from active badge sightings [4].
- **Responsive environment control.** The tab can be used as a general purpose, programmable remote control. In one research project the tab is used to control lights and temperature for the current location [5].
- **Migration Control.** The tab can be used to control window migration. Users can select from a list of X displays and cause windows from a remote display to be migrated to a nearby display [2].
- **Forget-Me-Not.** The application provides the user with an automatic biography of their life. The purpose of the application is to store daily activities of a user like where he went, to whom he met, what he did in a meeting, when he came back in office, when he took his lunch etc [3].
- **Email.** The email service application is used for sending and receiving email messages on tab. Filters can be used to group emails depending on context sensitivity. Urgent emails alert can be received during the conferences and meetings, but other don't [3].
- **Locator and Pager.** The application is used to locate the person needed in an office. People can decide whether to disturb a person or not on the basis of his/her location [3].
- **Communicator.** A context-sensitive media-space controller is used to allow users to establish video connection to various places in an appropriate wired building. The "Communicator" suggests the easiest way to communicate with the person you wish to contact and then help establishing the audio/video connection [3].

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