InfoPad - An Experiment in System Level Design and Integration

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Abstract

The InfoPad project was started at UC Berkeley in 1992 to investigate the issues involved in providing multimedia information access using a portable, wireless terminal. It quickly became clear that a key design constraint was the energy consumption, which could best be addressed through an integrated system approach. The project was therefore organized to address all design levels, including the applications and user interface, backbone network protocols, software for distributed network support, the wireless link, and the pad itself which used a number of low voltage ASIC designs and a processor running embedded code. Tools were developed when not available (particularly in support of low energy design), as well as an interface to mechanical designers who created a custom injection molded case. The wide scope of the project presented a number of unique challenges for a research environment and the lessons learn will be presented.

InfoPad Project Goals

The goal of the InfoPad project was to demonstrate a complete system solution to accessing and manipulating multimedia data (text/graphics, video and audio) from backbone network based information and compute servers as shown in Fig. 1. The user device, the InfoPad, was designed to be as light weight, low power and low cost as possible, essentially being set by the display requirements. In order for the user to *appear* to have large amounts of local storage and a high performance computing platform, it is necessary to provide high bandwidth wireless communications between the pad and the servers. The InfoPad system architecture supports this remote access by providing a network organization which allows user mobility while providing access to the network resources required to support the pads multimedia I/O capability. This was all to be accomplished under the constraint of minimum energy consumption in the portable units.

This required an investigation of low power hardware implementations for the wireless link and internal pad electronics, customized link protocols, mobile networking software and proxies which mediate between the mobility layer of the networking software and existing applications. In addition, it was necessary to develop new applications which exploit the unique capabilities of the InfoPad (e.g. pen and audio input without a keyboard), in order to demonstrate the full capabilities of the system solution being proposed.

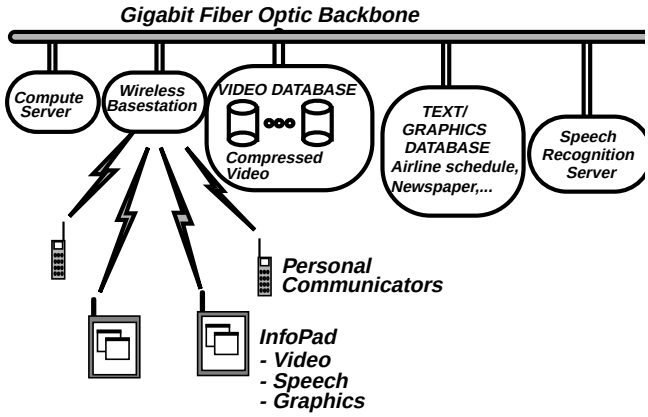

Fig. 1: The InfoPad system architecture

It is clear that the most complete power consumption reduction possible is achieved by completely removing the function from the InfoPad. If it is assumed a high bandwidth communication link exists between the InfoPads and the wired network, then it is only necessary to leave computation in the pad that supports the communications and I/O functions. This allows applications, storage and support computation to be performed on fixed network attached resources. This also was found to have advantages in other areas as well, such as cost reduction (e.g. low power and light weight mass storage is considerably more expensive than large server attached disks) and it simplifies the user support, since support is performed in centralized locations by knowledgeable system managers and not individually by the potentially vastly larger number of users of the portable units.

System Optimization

A number of important lessons and technologies have been learned and developed during the course of the InfoPad project research. It was hypothesized that a true system optimization should be attempted, which would range from the user interface, through the network and wireless link, to the terminal itself. Our results have clearly demonstrated that this was the correct approach in that the portable unit is significantly simpler than what could have been achieved by attempting to separately optimize individual segments of the overall system as is conventionally done. It was also important, in this system optimization, that even though we

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were willing to investigate custom solutions for much of our system design, it would have to be done in such a way that standard applications and network protocols could also be used. This would insure that full access would be available to existing network infrastructure and computational resources.

The overall system design involved a complex array of technologies, including low power design of digital circuits, design tools, signal processing algorithms, analog RF circuitry and network protocols. The communication algorithms which were investigated were designed to support high densities of users, such as might be encountered in a classroom with distribution of on-demand video. In addition to the dedicated circuits to implement these algorithms, for flexibility the implementation also involved embedded software, coupled with field programmable hardware.

The basestation which acts as a bridge between the wireless links and the wired backbone infrastructure, communicated with a layer of software which used an optimized protocol to support a variable quality of service for the multimedia data. The applications were buffered from this specialized software by a set of proxies which provided a standard interface.

At the next level was the middleware which supported the novel user interface requirements of the pad, which primarily was designed around speech and pen input, along with their associated recognizers and at the highest level were applications which exploited specific InfoPad capabilities.

Project Organization

To implement the overall system design it was found necessary to divide the project into five efforts which would focus on an individual parts of the problem and then to provide an organizational structure for interaction between the groups to facilitate the system optimization process. The areas that were identified were as follows:

1.Portable Pad Design- Design, fabrication and testing of the pad casing and internal electronics of the pad.

2.Wireless link- Implementation using commercial radios and research into customized monolithic CMOS implementations of TDMA and wideband spread spectrum radios.

3.Network - Software to support InfoPad mobility (InfoNet) and support for Quality of Service on heterogeneous backbone networks (Medley)

4.User Interface and Applications - Provides interfaces through proxies between the conventional backbone network and the InfoNet as well as “InfoPad aware” demonstration applications

5.Design Tools - CAD tools and methodology to support system level exploration and estimation of low power implementations and electrical-mechanical design

In order to coordinate these efforts and to facilitate the discussions was a continual challenge, particularly because of the nature of the graduate research environment. Due to the large number of people involved in the project (50-60 researchers), it was found that general meetings were not productive, and because of the non-hierarchical nature of an academic research project (at least at Berkeley), a strict assignment of work groups and responsibilities was also not possible. Particularly problematical was the dual focus of the project which required individual research efforts, that could ultimately result in a degree. These research efforts needed to co-exist with the development aspects of the project which required substantial additional effort in support of the infrastructure of the general project, with only indirect benefit to the individual’s research agenda. The ultimate motivation for the extra development effort put in by each participant, was the realization that the overall system implementation allowed investigations and demonstrations that would not be possible otherwise.

Fig. 2: InfoPad and Basestation

In order to keep the focus on real problems in system integration and to keep motivation high, it was decided to actually construct a number of terminals (20) (Fig. 2) and basestations and to attempt to use the resulting system design in our local environment. This clearly placed major requirements on the performance of the individual system components, since if any part either didn’t work or didn’t interact with other components the overall system could not be demonstrated. This involved uncovering the dependencies between the various groups that were inherent in the system design, that were often quite subtle or would fall in regions of responsibility that were not well identified. It is clear in retrospect, however, that by actually having real hardware and actually making it usable resulted in the definition of a number of new research endeavors that are still being investigated. Some of the most important of these are development of low power design methodologies which have yielded results that we could demonstrate on the InfoPad platform[2], new results in CMOS radio implementations[3] and the distributed software infrastructure which supported the remote computing model of the InfoPad system [4].

References

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