A Computer System for Accessing Ambient Display and Computing Resources in Wearable Environments

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Abstract

We present a novel mobile computer system and network architecture that overcomes display and CPU limitations on wearable devices. The system provides access to ambient display and CPU resources through a user interface tailored for use while mobile, on performance constrained devices. A lightweight network protocol transfers data and control messages in a power-efficient manner, and an application framework integrates model, view and controller while remaining flexible enough to support diverse datatypes. Our results show improvements in user interface latency and power-efficiency versus existing methods.

1. Introduction and goals

To allow users to more easily view the documents and information on their mobile devices, we have created the Astro Remote Display System (RDS), a mobile computer system and network architecture that enables opportunistic use of ambient computing resources. Just as public WiFi "hotspots" and rooms on corporate and school campuses equipped with projectors are now commonplace, various environments in the near future will have ambient computing resources available to roaming mobile users.

Our system consists of ambient display devices and mobile computers. A discovery protocol allows the mobile computers to locate the appropriate ambient computing resources within their environment. After the user has selected a resource, the file is displayed on the ambient display using a paired software architecture consisting of mobile control and ambient display components.

2. Discovery Protocol

We have designed a lightweight discovery protocol for RDS that can: (1) Detect the display and computing resources in the immediate environment and determine the relative physical location with respect to the user; (2) Query resources to determine their processing and graphical output capabilities; (3) Form and break connections quickly between the user's mobile device and the resource.

The current protocol works over IP, with the ambient resources (displays, processors, etc.) broadcasting UDP packets at periodic intervals. Each packet can be variably aimed in network scope: some packets can be sent on the local subnet only, while others can be broadcast to the next subnet up and so on (as long as the intermediate bridges, gateways, and routers are configured to allow such behavior).

3. Mobile Device

The user interface of the mobile device changes its functionality and control types based on the datatype being manipulated. The user interface framework is comprised of application component modules called AppModules, Each AppModule is associated with an ambient display component and datatype. The memory footprint of an AppModule is currently around 100KB. AppModules can be quickly loaded and unloaded at runtime, so the memory footprint can be efficiently managed. There are provisions for multiple AppModules, up to the limit of memory and screen space.

4. Ambient Display

The Ambient Display, like the mobile user interface, operates in a modular, data-centric manner. It consists of two layers: the network listener and filetype-specific DispModules. The network listener accepts requests to display files, loads the appropriate DispModule, then routes the file to it. Each DispModule reads the file from the network layer and responds to commands sent by the mobile user interface over the network. For example, the video player DispModule is capable of decoding and displaying the video and responds to commands to rewind or pause the video.

5. Network Impact Analysis

One of the key differences in the way that our sys-

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tem works versus VNC-like systems is that our system sends a large amount of data to "preload" the file so that later control messages can be short, much like a cache. Once the file has been transmitted, only control information is sent over the network, rather than control and display information.

Figure 1 shows the result of the video test. The columns on the left represent the video clip played back from start to finish. The network usage is approximately comparable. The right columns show a seek operation into the middle of the file (after it has completely loaded) followed by 15 seconds of playback from the location. The RDS case has significantly less usage, since it sends only the control data and the video data is already on the display device. VNC must resend that portion of video.

Figure 2 shows the results of the Portable Document Format (PDF) file test case. These results show that the initial "preload" is a good tradeoff for efficient performance while browsing the document.

6. Power Impact Analysis

Figure 3 shows the moving average of Watts of power consumed by playing back the sample video used in the network bandwidth analysis. VNC consumes significantly more power than our system, particularly after our system finishes transmitting the file (which occurs at around 75s).

Figure 4 shows the moving average of Watts of power consumed while zooming in four times on the PDF document.

7. Future Work

We envision a device the size of a keychain fob, like the current style of keychain USB memory keys. A flash memory connector provides storage for the user's data. A low-power, short range radio provides the interface to the ambient resources. The controls would consist of a small 8-way rocker switch and a few buttons, that work together to provide page and screen navigation capability. When connected to an ambient display, a menu on-screen would show all the available files in the mobile device's storage and allow display and navigation of a file's data.

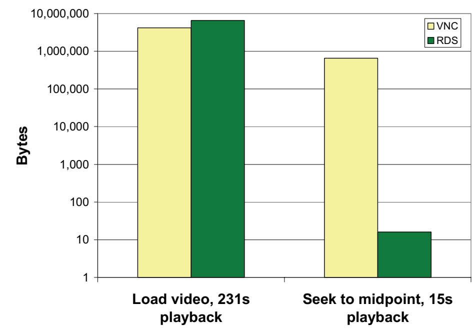

Figure 1. Video playback; full load and playback (left). When already loaded, seek, then 15 s playback (right)

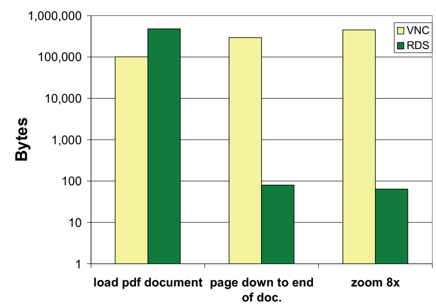

Figure 2. PDF document test; Document load (left). When loaded: "Page down" to the end (middle), Zoom-8x (right)

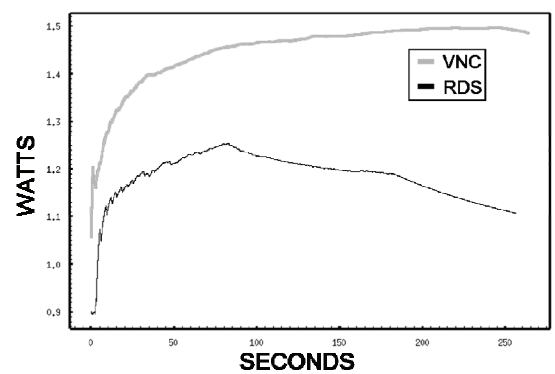

Figure 3. Moving avg. of power (W) for video playback.

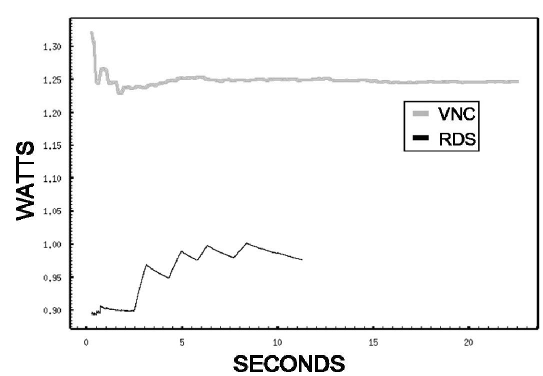

Figure 4. Moving average of power (W) during PDF zoom