Face-to-Face Media Sharing Using Wireless Mobile Devices

Trevor Pering*, David H. Nguyen+, John Light*, Roy Want*
*Intel Research; +University of California, Irvine
trevor.pering@intel.com, dhn@uci.edu, john.j.light@intel.com, roy.want@intel.com

Abstract

Advanced personal wireless mobile devices, such as today's emerging smart-phones, are capable computers that have the potential to enable individuals to share personal content, such as photographs, music, and video. Face-to-face sharing can be a satisfying and even emotional experience, yet it is not well supported by existing digital technologies, which typically isolate media into separate collections or require that they be manually combined into a single collection on a single machine. Federating wireless mobile devices with fixed infrastructure, such as a digital home entertainment center, provides a lightweight, unified, and intuitive way to share media among friends and family. This paper looks at both technological and social issues that surround sharing media using federated devices, considering the relevant emerging technologies, media types, and usage contexts.

1. Introduction

Federations of devices are a new phenomenon enabled by emerging wireless mobile technologies, which are poised to provide new ways of sharing personal digital content in face-to-face situations. A federation, in this context, is a collection of independent devices aggregating to provide more extensive capabilities than would have been possible individually. Such federations address the fundamental limitations imposed by mobility and portability – small displays and limited processing power – by leveraging short-range wireless connections between the mobile devices and local infrastructure, extending the Personal Server [10] concept, which views mobile devices as full-featured computation and storage servers. For example, a user can use a home PC to view content stored on their mobile phone, federating the PC and phone to form a more capable system.

A key feature enabled by short-range wireless federations is the ability for multiple people to come together and share content *face-to-face,* not just sending or posting information using email or internet-based services. For example, in addition to posting their vacation pictures on a web page for their *extended* friends and family to see, users could discuss their pictures face-to-face with close family members, engaging in an rewarding discussion about their trip. Currently, this practice is possible using laptops or desktop computer, full-featured systems with a large display that happen to have the images stored on them locally; however, this interaction is not well supported by small mobile phones which can capture and store the content, but are extremely limited in their ability to display the information: Several people huddled around a small mobile device do not usually have a rewarding experience. Combining these two techniques, federating phones with larger display devices, enables people to locally share content in a more engaging manner.

Figure 1: State-of-the-art cell-phones such as the Motorola E680 already have the basic capabilities necessary for federated sharing.

There are several media types that lend themselves to face-to-face sharing, the primary candidates being: music, photographs, and video. Each of these types has defining characteristics, such as bandwidth, attention requirement, and system power consumption, which affect both the technology required to support sharing and the environments in which sharing might be appropriate. Music, for example, has relatively low-bandwidth requirements and can be consumed as a background resource, while videos, in general, have high-bandwidth requirements and typically consume a user's full attention. Understanding the characteristics of these media types yields an understanding of how and where they might be shared.

To understand the potential for new usage models and to demonstrate the feasibility of federating devices, a prototype system that federates commercial mobile products (Figure 1) with standard desktop and laptop systems highlights mechanisms that can be integrated into emerging standards to support novel and compelling applications. The prototype builds on standard protocols originally developed for the world-wide web, such as http, web pages, and streaming video, to construct a mobile federated ecosystem. Casting this prototype into the digital home, public space, and digital office usage models then highlights how these supporting technologies can be used in multiple environments to enable the associated usage models.

2. Motivation

The basic motivation behind face-to-face sharing using federated devices is the desire to support emotionally rich experiences. Often, people share photographs and other personal media through email or a web site, sending their pictures to their friends and family, but not actually participating in the sharing process itself. Currently, people *can* share their content, but it often requires juggling cables and data conversion between storage and display devices – resulting in a less-than attractive sharing experience; systems enabled by advanced mobile devices and emerging consumer electronics standards will provide new capabilities that allow people to share their digital media in an intuitive way. As computing technology becomes faster, smaller, and more functional, it is being used to strengthen both social and emotional bonds between people [9].

The supporting force behind federated devices are the emerging mobile devices that are starting to have many capabilities necessary to support media sharing scenarios. Specifically, trends in increasing storage capacity, low-power mobile computation, and short-range wireless networking allow mobile devices to seamlessly connect with the environment around them. Many of these products now run full-featured operating systems such as Linux, which give them advanced capabilities that were traditionally only available for desktop or server systems. Given that the basic cell phone platform is already very popular, it is reasonable to assume that advanced capabilities based on these emerging trends will soon be available in a wide spectrum of mobile devices.

Likewise, emerging standards in the digital home space are starting to provide a strong foundation for supporting interaction with mobile devices. The Digital Living Network Alliance (DLNA) [1] is drafting standards and specifications to enable interoperability among consumer electronics components in the home. This technology, for example, aims to allow you to easily view content stored on your home PC through your living room TV – seamlessly integrating the various devices in your home. This network of media devices provides the basis for accessing content stored on wireless mobile devices that, along with their human hosts, can dynamically move in and out of the environment. Although nominally targeted at the home environment, these enabling technologies will also enable federation in other environments, such as public places or the digital workplace, using the same technology to support different usage models.

3. Media Types

There are three main media types commonly represented in digital formats: music, photos, and videos. Each of these three types presents significantly different technical requirements (in terms of bandwidth and access latency), and support different usage models based on how they are consumed. Photos and videos, for example, are both visual in nature, but afford very different interaction patterns (dynamic random-access vs. sit-and-watch). The differences between these types, and how they impact federations of devices, are discussed below. Other media types, such as vector animation or complex games certainly present compelling and interesting channels, but currently do not represent significant content for digital systems.

Communication bandwidth is an issue that relates to all three media types. Synchronization and transfer of a large collection is bandwidth intensive, but updating an existing collection may be less so. The technical challenge is to use bandwidth efficiently, without unnecessarily draining the device's battery. One approach to this problem is to take advantage of the multi-radio capability that is now available in some of the high-end devices – using both WiFi and Bluetooth, for example. A complete discussion of the topic is beyond the scope of this paper, but can be found in [6]

Music: *Low bandwidth, passive, streaming*

Portable digital music, the most recent successful embodiment being the Apple iPod line of mobile music devices, is popular because it can augment a user's other activities. For example, people can listen to music while driving a car, walking down the street, reading a book, carrying on an unrelated conversation, or any number of other similar tasks. However, it does become the center of attention when somebody would like to play a song specifically for somebody else to hear; in fact, music is often used as a component of personal identity [4], and used to project a particular persona.

From a technical perspective, music is utilized in two main capacities: playing and synchronizing. Playing is relatively easy – high quality audio can be wireless transmitted at less than 256 kbps, a bandwidth easily supported by Bluetooth and other wireless technologies. Synchronizing, the process of quickly copying a collection of songs from one device to another, can consume the bandwidth of any existing mobile wireless standard for many hours, as personal collections can exceed multi-gigabyte capacities. In this case a more satisfactory approach is to explicitly plug in a cable and take advantage of one of the high bandwidth serial protocols, such as USB 2.0.

Photos: *Mid bandwidth, interactive, random-access*

Camera phones outsold digital cameras in 2004 by nearly 4 to 1 [7], with an estimated 60 million photos taken daily. Furthermore, the quality of pictures taken with camera phones is rapidly increasing, and although they are never likely to match the quality of larger digital camera devices, their picture quality will eventually surpass the “good enough” threshold for many people. Because of this capability, camera phones will inherently contain many photographs that their owners may wish to share with other people, but the small screen on the phone itself will likely be too small to effectively show them.

Most digital photographs can be transferred in reasonable time over even the “slow” connection of a Bluetooth link, which provides upwards of 500 kbps bandwidth. On the other hand, photo viewing tends to be very interactive – people will select individual photos, talk about them, and then manually move on to the next one – making it important to have quick access to portions of a large photo collection. Furthermore, personal photos are less encumbered by copyright issues than commercial music and videos – making them a prime candidate for showing, sharing, and trading using federation technologies.

Video: *High bandwidth, high-attention, streaming*

Face-to-face video sharing is similar in some respects to sharing music, i.e., displaying a stream of media for somebody else, but is both a higher-bandwidth and higher-attention activity. For example, it is less likely that somebody will just put on a video in the background and then go about other activities. Video is an attractive medium because it encompasses both sound and pictures, effectively combining music and photographs. Currently, many mobile devices are not sufficiently powerful for showing video – either they don’t have the storage capacity for a video of the appropriate length, or their screens are too small for an enjoyable viewing experience; however, the already discussed capabilities of advanced federated devices will provide the necessary storage and viewing capacity to enable video as a viable mobile media.

Since this media has higher-bandwidth requirements than music or photos, video will stress the base technical capabilities of a wireless federated system. Fundamentally, the basic Bluetooth link is sufficient for supporting reasonable-quality video at a resolution suitable for an airplane seat-back display. As with any mobile device, power consumption is often a primary concern, and video will place an increased demand on system resources; however, in a federated model, since the video is being played on the fixed infrastructure, the mobile does not have to supply the power for the display, which will lead to a net saving in comparison to other self contained products such as a Personal Media Players that render the video locally on the device.

4. Environments

The basic technologies provided by emerging mobile devices and digital home infrastructure can be applied in a variety of contexts, each with its own set of requirements and capabilities. There are three common contexts to be considered: the digital home, public places, and the workplace. The digital home is fertile with many emerging technologies and is driven primarily by the consumer electronics business. In public places, people frequently use their laptops, particularly when the places (e.g., cafes, book stores, and airport) support a Wi-Fi connection to the internet. Solutions developed for the office environment have significantly different objectives than those associated with media access in the home, but the environment itself is rich in digital infrastructure, naturally lending itself towards supporting federated devices.

The digital home environment can be loosely characterized by a need for easy-to-operate interfaces that would be primarily used to consume media, for example, to easily view pictures from a recent vacation, or watch a favorite music (Figure 2). In this environment, the systems must be as easy-to-use as existing consumer electronic devices such as a television or stereo system. Security concerns are not as significant compared with other domains because most people have a greater level of trust in both their home infrastructure and the friends/family that will

Figure 2: The digital home focuses on accessing and viewing digital content – enabling people to share media through familiar consumer electronic devices.

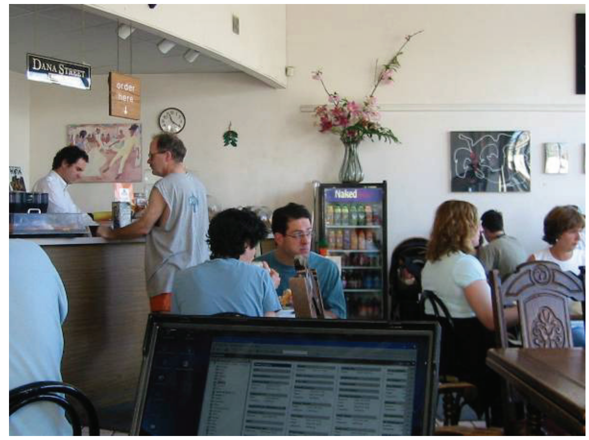

Figure 3: Public spaces can support media sharing to help explore new applications.

be consuming the content. The challenges in this domain come down to integrating mobile media devices with consumer electronic devices, e.g., viewing pictures from a personal cell-phone on a friends TV, without direct interaction with traditional computing system such as a desktop PC.

Interacting with personal media in public places (Figure 3) such as a café or airport kiosk opens up entirely new possibilities for interacting with digital media while presenting significant challenges in the area of privacy and security. Sharing media using federated devices in this kind of space means utilizing either public or borrowed infrastructure to accomplish the task, necessitating a higher level of trust. This use of public infrastructure also opens up systems to virus attacks, potential user tracking by the infrastructure, and DRM concerns. However, if these concerns can be adequately addressed, the capability to consume personal media in a public space has great potential for widespread use. For example, people could view a favorite TV show or movie while taking an airplane trip (using a seat-back screen to view content stored on their mobile device), or play some of their favorite music through the digital jukebox in their local café or bar – usage models that can extend the reach of personal content far outside the limited home environment.

The workplace, which is significantly different from the home environment with respect to the kinds of content that would be shared, presents institutional challenges that highlight security and reliability issues, but will generally be better equipped in terms of the basic infrastructure resources available. In the proverbial company presentation example, where a business traveler would like to show a presentation to a customer without having to carry a laptop with them, the presenter would often like some guarantee that their presentation will not be copied as they show it (assuming it has sensitive material), and also that the customer's digital projection system will be compatible with their mobile device. In essence, the standardized interface in this example is shifted from the ubiquitous VGA cable to a higher-level wireless TCP/IP interface. Within a corporate IT environment, which is generally standardized and relatively advanced in its capabilities, it is likely this kind of mechanism can flourish as users will be guaranteed the availability of suitably enabled infrastructure.

These three environments highlight the different needs and concerns that face a system designed to share content based on federated devices. The digital home and workplace environments are presently fairly well poised to support federated interaction; public places, however, are currently streamlined to support isolated islands of interaction where people use either their personal laptops or internet kiosks, and arguably have further to go to support federated interactions.

5. Architecture & Prototype

A prototype implementation based on a commercial cell-phone platform demonstrates how federated devices can be used to support media sharing in a variety of contexts. In this prototype, a cell-phone is augmented with Personal Server capabilities, making the device responsible for storing and serving a user's media files, including those taken with the phone's camera, while devices in the infrastructure are utilized for viewing and interacting with the content. The overall system

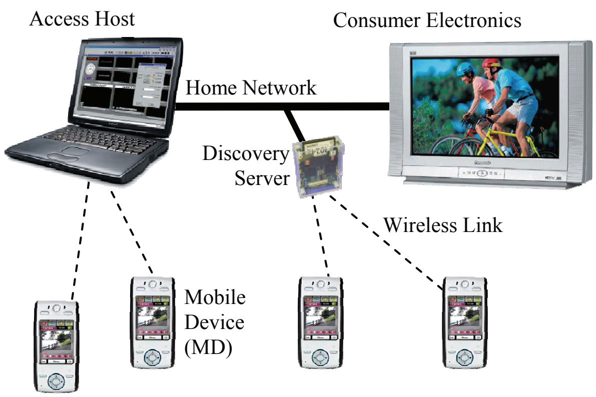

Figure 4: Federated devices media-access architecture, with Mobile Devices and supporting infrastructure

architecture is shown in Figure 4, depicting multiple mobile devices in conjunction with the necessary supporting infrastructure.

The Mobile Device (MD) used in this prototype is a commercially available Motorola E680 phone augmented with custom software to enable it to serve a variety of multimedia content – effectively adding Personal Server capabilities to a mobile phone. This device has a 300 MHz low-power processor, 32 MB of built-in SDRAM and FLASH, a Bluetooth radio, and an external MMC/SD card slot (with a 1 GB SD card). The basic device, using the Linux operating system, has been modified to run a web server, file server, and streaming media server, and a UPnP [8] Device, shown in Figure 5 (along with the corresponding infrastructure client architecture).

The content on the MD can be directly accessed from any Access Host, which can be a standard laptop or desktop computer that can form a standard Bluetooth Personal Area Network (PAN) connection with the MD. This connection, which provides a TCP/IP link to the device, enables standard applications such as Internet Explorer, Windows File Explorer, and the QuickTime Media Player to render the MD's media content. Once connected to the Access Host, the device is discovered as a UPnP resource on the network, allowing intuitive access to the other servers from a the user interface of the WinXP based machine. From the client's perspective, the MD acts just like any other standard server, utilizing the wealth of applications supported by the TCP/IP networking layer, avoiding modifications of the Access Host.

In some environments, a Discovery Server component can act as a bridge between the MD and infrastructure components, such as Consumer Electronics devices, that are network enabled but can't talk directly to mobile devices. In its simplest form, the Discovery Server is similar to a traditional wireless router or gateway device; however, it also provides discovery and connection capability *from* the infrastructure *to* the MD – allowing programs and applications running in the infrastructure to connect to the MD without being initiated from the MD. This component provides an easy path for integrating mobile devices with fixed infrastructure without requiring specific capabilities in pre-existing infrastructure components.

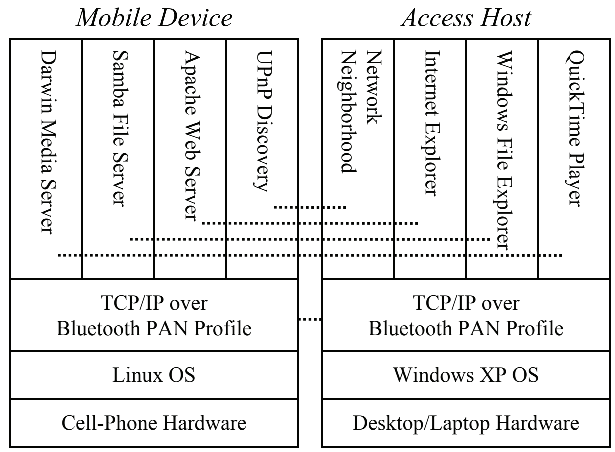

Figure 5: Software architecture of the Personal Media Server system.

The prototype demonstrates the technology's potential to support federated media sharing among mobile devices, covering all the basic media types, which can in-turn feed into all three target environments:

- **Music Sharing** [*Public*]: The system can easily support playing mp3-encoded music from mobile devices, enabling a public display of music, where people could easily play their music for other people in a bar or café..
- **Photo Sharing** [*Home*]: By mounting multiple file shares at the same time, the familiar drag-and-drop desktop interface can be used to view and share photographs among multiple devices.
- **Video Streaming** [*Home*]: Video requires greater system capabilities than the other media types, but it is still possible over the Bluetooth link with videos encoded at rates of 384 kbps upwards, resulting in a watchable 480x260 mp4 video.
- **Business Presentation** [*Office*]: Although not a basic media type, a business presentation might include videos, photographs, and music as well as a spreadsheet. The basic presentation can be

accessed through a web-browser front-end, in turn launching an integrated presentation viewer.

In all of these cases, standard PC-side applications (media player, drag-and-drop transfers, and office productivity software) are used to access and even edit the content stored on the users' mobile devices. In short, this system prototype gives access to a host of application capabilities without extensive system development. Of course, these are just proof-points of how the various media types can be used in the different environments, and many other combinations are possible.

6. Discussion

Beyond demonstrating basic technologies, the prototype also highlights how these technologies can support use in different environments. Specifically, it provides a concrete context for exploring issues with Digital Rights Management (DRM), privacy, security, and focused application integration. Although these issues are of course applicable to any media system, it is difficult to explore them extensively without the concrete instantiation provided by the prototype.

Digital Rights Management (DRM)

DRM is necessary to extend the current model of content distribution to federated systems. With any sharing of copyrighted digital content, the content owners need to be reassured that that their media will be protected from illegal distribution. Conversely, a compelling media sharing experience can actually further the interests of copyright holders by creating more demand for their content.

Many of the same standards that have been developed for web-based content can be applied to the federated devices scenario: for example, the same mechanism that allows you to play a streaming video from the Internet but not copy it to your local hard drive would allow users locally view a video without allowing them to arbitrarily make copies of it. However, as indicated by complaints from users trying to manage personal music collections on multiple devices, truly flexible migration of content to/from the federated device is likely to cause some potential problems with existing DRM implementations..

One insight into how federated devices might support the sharing of digital content is provided by examining the underground emergence of a phenomenon called "iPod Nights." For these events, a group of people who own iPods meet together in a bar and share their music with others by taking turns to dock their devices in a cradle linked to the establishment's sound system. They also write the name of the song they are playing on a whiteboard, for those who are interested [2]. This model has met with limited success, arguably because the basic interaction is fairly heavyweight. Imagine, instead, that anybody could play a favorite song or automatically capture the metadata for songs playing around them – and then reference that song at a later date, possibly to purchase it for themselves. This kind of streamlined sharing would remove barriers for this usage model, and make it more attractive to the content providers.

Privacy – Identity and Public Image

Privacy is a topic that is often raised in any kind of data-sharing context, because people are sensitive to the kinds of data that are shared about them. In the context of federated devices and media sharing, the privacy concern can be cast in the form of "Identity Management" – i.e., not in the black-and-white sense of "*is* one's privacy maintained?", but rather "what am I giving away about myself when I provide information about my music collection through a wireless interface?"

For example, consider the sharing of music in public places. At a very basic level, music is a representation of one's identity, and the songs that one might choose to share represent a projection of this identity into the digital space. From the perspective of the prototype, this would translate to both the Bluetooth identity of a mobile device, and the basic web-page that is served by the device when publicly accessed. So, for example, a user's device might say "Bob's Mobile Phone" and show a simple page with the owner's picture and basic public contact info. This presentation might be appropriate in a conservative business context; however, if the user is attending a social gathering, such as a hip party, they might change their expression of identity so that their phone would call itself "Bob's Funky Phone" and provide a list of Bob's favorite funk hits from the 70's and 80's.

The behavior of managing multiple identities currently manifests itself both physically in the style of dress that people wear, and technologically when people can change the faceplate on the mobile phone or adorn their device with stickers. So, while people tend to dress more conservatively for work, they often dress up for a night out on the town. The key, in a technological context, would be to provide a mechanism for users to easily create and manage identities. Similar to the DRM context, the ease of use for this model would be critical for its successful adoption.

Security – Trust and Protection

Security is a concept that, similar to privacy, requires attention across a variety of contexts. Each level of security is related to the trust associated with the current context, and for federated devices this primarily translates to the trust that users place in the Access Host. If the Access Host might be compromised, for example, by spyware or a keyboard logger, then a user's password may become compromised as they type it in. However, in many contexts, such as the digital home, it may be quite appropriate to trust the Access Host, since it is part of a known environment

Photographic Authentication [5] is one technique developed in the context of the Personal Server that enables controlled access to personal data without using passwords. The basic premise is to require a user to identify a sequence of personal photographs mixed in with other random images – something they will be easily capable of doing, but someone else will not. Since people can easily recognize a very large number of their own photographs, a different selection can be used each time, making the basic authentication process immune to replay attacks. So, although a compromised Access Host may be able to glean some personal data from the interaction, such as capturing data that the user accesses via the compromised Access Host, the user's password, which is much more sensitive, is not compromised.

Although Photographic Authentication provides some level of protection for accessing semi-private data through un-trusted Access Hosts, it will not be appropriate for all contexts – specifically as a technique to protect more secure data. However, it would not be wise for a user to want to access highly sensitive data, such as back account information, directly through a public terminal, and instead reserve this type of use for more trusted home or office infrastructure, or use the limited display capabilities of the mobile device itself. The key observation here is that the level of security should be appropriate for the level of trust in the federated infrastructure, and that systems should not rely on an all-or-nothing security policy commonly found in existing computer systems.

Application Integration

The prototype provides basic multi-user interaction to enable federated media sharing without requiring significant installed software on the client side. This (lack of) requirement is important for enabling widespread adoption of the technology; for although it is reasonable to assume that every potential Access Host in the infrastructure will support a basic web-browser, it would not be safe to assume that they would provide an integrated multi-media sharing application. However, using standard web protocols supported by the common web browsers (e.g. Internet Explorer) it is possible to enable the proliferation of more tightly integrated applications.

The basic sharing technology supported by the prototype is a simple drag-and-drop interaction layered on top of Microsoft windows file-sharing capabilities extended to the mobile devices: users can mount their devices as standard network drives, and simply copy files between them. Although this works well for two people, it does not scale well to larger sets. Consider the case of four people gathered around a screen sharing photographs from their last vacation – the problem of browsing through four separate photo collections and individually copying desired photographs among all four devices could quite easily make the system too difficult to use. A specialized application designed to share photographs among multiple people can streamline this interaction

Web technologies such as Java Web Start [3] can allow devices themselves to provide the applications, and then a custom application can render a user interface that is tailored specifically for federated interaction. As long as one device has the necessary code, it could be used to access the content on all available devices. In a sense this represents sharing of applications, which has the potential negative side effect of allowing viruses to propagate.

7. Conclusion

Federated devices used for face-to-face sharing of multimedia provide a powerful new platform for mobile interaction. Instead of relying on the small displays of mobile devices, users can utilize the larger displays found in the environment to access personal data carried with them at all times. This model, which is built upon the emerging technologies of advanced cell-phones and digital home infrastructure, supports activities in the digital home, public places, and office environments.

The prototype, based on a commercial cell-phone platform integrated with laptop and desktop computers, shows how existing technology supports the basic federated device scenario. These technologies, however, can still be augmented with additional components, such as DRM or web-application systems, borrowed from the traditional

Internet world to augment the basic functionality. Additionally, the federated devices model provides unique challenges in the areas of privacy and security that can be addressed by new concepts and techniques developed specifically for operating in semi-trusted environments.

Using the federated devices approach, applications and services will enable friends and family to come together and share engaging experiences, instead of merely functionally sharing media through an Internet based web-page interface. Although it will not replace distributed sharing for geographically-extended social circles, the face-to-face aspect provides a new level of communication not available with current mobile digital devices – it will enable people to emotionally connect and interact with each other, instead of sitting alone, in front of a computer "connecting with each other."

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