CovertFS Implementation

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Abstract—In 2007 Arati Baliga, Joe Kilian, and Liviu Iftode of Rutgers University presented the idea of a web based covert file system [1]. The purpose of a web based covert file system is providing confidentiality and plausible deniability regarding the existence of files. The key components of a web based covert file system is hiding files within media using steganographic techniques using online file sharing for the purpose of collaboration [1]. We created such a system, covertFS, as a prototype to develop the idea for a web based covert file system previously mentioned. Our prototype of the web based covert file system implements steganographic techniques to obfuscate an entire file system on a public file share site. By storing data in this manner, rather than within the application or on a users computer, we provide confidentiality and plausible deniability to both the users and the companies that manage these public file sharing sites.

1 Introduction

Technology continues to integrate itself more and more in our daily lives because of the convenience it provides to users. Users are becoming connected to the internet in multiple ways nearly everywhere they go. The Internet of Things keep users engaged and updated on their various interests. Today, a user will typically have at least a cell phone on their person on which they will browse email, social media sites, and use various other applications. These applications themselves, regardless of the convenience they provide users, can track and offer the user the option to post their information on the user's social media site profile to share among friends and acquaintances.

The majority of people interact with multiple forms of technology throughout each day. Some technologies we interact with collect data from our interaction. Also, the widespread use of social media makes it easier to find information about people. Technology, coupled with social media and other applications, can begin to paint a picture used to identify individuals with only non-identifiable information [? Ad platforms, etc]. Sometimes this data collection is used solely to advertise a product to you, but sometimes there are more nefarious means of data collection that lead to black mail, social engineering attacks, or worse. Even if the technology and the application is secure, maybe the service provider itself is not[1].

The means to store and share information in a covert manner not only serves multiple purposes, but also has various implications depending on how those means are used. There will be innovations designed with the good intentions, yet there will also usually be clever modifications of those designs for malicious intentions. (Identify good and bad use cases?)

This project is an application that allows users to share information in a covert

manner that can provide plausible deniability to not only the users but also to the file sharing or social media site used to store the information. Plausible deniability is the indetermination that the data exists with certainty and confidentiality is the idea that the hidden data cannot be uncovered[1]. Even if the existence of the file system is uncovered, the data should remain protected and confidential.

2 Related Works

There are other projects and systems that have been released which offer users covert methods of sharing information. Such examples include Tor and StegFS[3]. In 2007 students and faculty from Rutgers University provided the main concepts and basic outline for the implementation and design of a covert file system[1]. There has been no other implementation of the application described in Rutger's paper, and this project is our take at creating a working prototype which could later be used to develop a successful application or implementation of the covert file system.

3 Design Overview

In this section we will explain how we decided to implement a prototype of this project.

3.1 Web Connection

Our application's interface with the internet needs to serve three purposes:

1) Retrieve pseudo random images to use for embedding a message.
2) Upload images to a public online forum anonymously without altering the image.
3) Retrieve specific images from a public online forum anonymously without altering the image.

After some research, we discovered a service that could satisfy the first purpose. The Cat API provides random cat images retrieved from Tumblr. The API is reliable and returns content neutral images big enough to store information. A downside to this approach is that statistical steganalysis can be done to compare the uploaded images to the originals. The possibility of using local unique images is out of the scope of our project. The next two requirements are fulfilled by Sendspace.com. This website provides an external API that allows our application to easily interface with and upload and download full size images anonymously.

The online resources work together as follows:

1) The Cat API retrieves a random cat image for a message to be embedded into.
2) Embed data into image.
3) Upload the encoded image to Sendspace. Sendspace returns and download and delete URL.
4) Download the encoded image using the download URL.
5) Decode the image to restore original data.

3.2 File System

The file system in covertFS is built off of the *pyfilesystem* python package, available on the Python Package Index. *Pyfilesystem*, or *fs*, provides a framework of different modules that can access file systems in different locations- one module accesses the running operating system's file system, there is a module for accessing NFS, and finally there is a module that creates and accesses a file system in main memory. This memory-accessing module is called MemoryFS.

MemoryFS is the superclass for our custom file system class, named (yes, it is the same as the project name) CovertFS. CovertFS utilizes CovertFiles (subclassed from MemoryFile) to store the data in files, and CovertEntries (subclassed from MemoryEntry) to store the file metadata (MAC times etc.) of all file system entries, including data files and directories. The CovertFS class also adds functionality to work alongside the web connection module of the project, such as the url the corresponding picture can be found at, initial creation time, etcetera.

In order to mount the user-defined, external, stored-in-memory file system to the native operating system file system, we must use the File system in User Space, or FUSE. FUSE is written in C (to better interact directly with operating system), but there are APIs to use it in other languages— including Python 3. The python package *fusepy* was our key to accessing FUSE functionality. It provides an easy to use layout for writing a FUSE file system in Python. A FUSE file system is written by defining a function for a list of operations that must be able to be carried out by the operating system— basically a user definition of how to access each command that can be entered in a command line. Our implementation of this OPERATIONS class is called MemFuse, and it includes a CovertFS object as a parameter. This allows for dynamic variables to be set by the native operating system (through MemFuse), but then later be accessed by the main function, to upload to the online directory of pictures.

3.3 Mapping File System Data to Photos

How is the data stored in our file system, and how it is constructed.

3.4 Steganography and CovertFS

The primary purpose in a web based covert file system is confidentiality and plausible deniability. Using steganography can provide both confidentiality for users as well as plausible deniability. However, steganography also has risks that make it vulnerable to both. Statistical analysis and visible alterations (anything else? – research) can make steganography detectable, thus removing the aspect of both confidentiality and plausible deniability. However, there are ways to reduce the risks of using steganography.

3.4.1 Risks Using Steganography

The greatest risk to using steganography, particularly our steganography module, is that an embedded message can be discovered using statistical analysis. Since the original images exist on Tumblr and can be retrieved using the Cat API, our images that get uploaded to Sendspace can be compared to the originals. Statistical analysis between the original and the modified images will indicate that a message has been embeded. There are alternative steganograhpy techniques, but their are still several steganalysis tools to detect them [2]. Not only can steganalysis detected changes, but they are visually apparent as well. Figure A shows both an encoded image and its original. The discoloration at the top of the encoded image is from the LSB encoding and this shows an obvious visual discoloration that an adversary can easily detect.

3.4.2 Mitigating Risks of Steganography

These risks are mitigated by the fact that there is no universal standard for steganography methods. A user can easily replace the steganography module that we offer with a module of their own. That way,

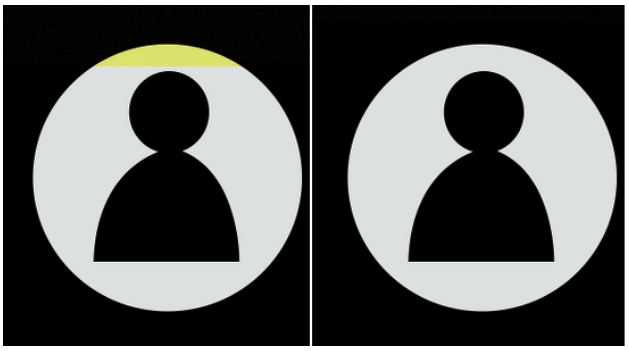

Fig. 1. Figure A. Left: encoded, Right: original

even if someone knows an image is not the original, that person will still not know who encoded it, or what kind of module was using for the encoding. Also, an encryption module can easily be added to our application and used to encrypt messages before they are encoded into an image. So even if someone knows what kind of steganography module is being used to encode messages into images, that person will also have the added challenge of decrypting the information. Although, there is no research to indicate that encryption helps in fooling steganalysis tools. Finally, since the original images exist on the internet, it will limit the plausible deniability of the user. It can be called into question as to why a certain user is uploading images that do not belong to that user to an online image database.

3.5 Encoding a File System

The covert file system uses a drop in steganography module that takes in a bytearray object and returns a URL to an image. We used ”least significant bit” steganography for this application because of its simplicity and reliability.

3.5.1 Steganography Implementation

Least significant bit (LSB) steganography is a Substitution type of steganography [**?**] that replaces the least significant bits in the image's pixels. Our steganography module is not true LSB steganography because we replace multiple bits in each pixel allowing us to encode one byte of data into every pixel. We designed our steganography technique this way to decrease the amount of images required to encode large file systems at the cost of only minimal discoloring.

First, we break every byte of the message into three segments. Two segments of the byte will contain three bits, and the last segment will contain two bits. Next, we replace the three least significant bits of the red component with the first three bit segment. The green component follows, with the replacement of its least significant bits with the second three bit segment. Lastly, we replace the two least significant bits of the blue component with the remaining two bit segment of data.

There are obvious drawbacks to our implementation of LSB steganography, primarily that the image may appear distorted as seen in Figure X and CovertFS images are X percent easier to detect using standard statistical analysis techniques compared to true LSB steganography as seen in figure X. However, this implementation enables us to store more bytes than other implementations of LSB steganography which decreases the latency in uploading and downloading images in large file systems [? Need evidence].

3.5.2 File System to Images

The first step in encoding a file system is retrieving an image. We use ”The Cat API” which retrieves a random cat picture from Tumblr [?]. Once we retrieve the image, we determine the number of bytes we can encode in the image by multiplying the height and width of the image, in pixels. Since we encode one byte per pixel, the

result of height times width results in the total number of bytes, n, of data we can encode in the image. For example, a 640x480 pixel image can hold 307,200 bytes of data. Next, we take the data we are going to encode and append a special end of file byte encoding. Then, we break the data into two sets, one containing the last n bytes and the other the remaining bytes.

Next, we encode the data in the first set into the image and upload the image. We retrieve the URL of the uploaded image and append a URL identifier byte encoding along with the URL itself to the remaining data. Then, we repeat the encoding steps by appending the end of file byte encoding, splitting the data, and uploading until there is no data left to encode. At this point, we have encoded all the data and have a ”linked list” of encoded images containing the data. Finally, we can return the URL to the head image of data.

4 Conclusion

An implementation that would increase the flexibility and security of this project is developing the covertfs into the TAILS operating system and having it run as a bootable program through the a flash drive. The reason for this is because the TAILS operating system in and of itself offers various security measures to ensure a stable and fucntioning system. We are working to develop a working prototype where our covertfs is integrated in the TAILS operating system to further allow confidentality and plausible deniability to the users.

4.1 Tails

Tails will be completed prior to publication. TBD.

4.2 Future Work

Our current implementation of covertFS does not require any user authentication, it only requires the 6-character code of the file system image to access all files in the system. We use versioning (i.e. the current version of the file system uses this code, if you change anything then a new code will correspond to the new file system) to protect the information stored in the file system from being deleted— we don’t ever delete images from the online file storage site, even though some sites allow it. An alternative approach could require a user to have an account with the covertFS database. This would take away the idea of plausible deniability, as every user would require some sort of entry in the database. However, it could add to the confidentiality of the file system, as only authenticated users would be able to access the data. Another possibility would be to add a simple password entry into the encryption suite. This could increase confidentiality, without removing plausible deniability.

4.3 Encryption and Advanced Steganography Techniques

Another future implementation worth looking into is the use of a more advanced steganographic technique. The purpose of this is to ensure the confidentiality and plausible deniability of the users by:

1) Ensuring that pictures being used to hide the information do not give tell-tale signs of modification
2) To increase the difficulty of steganographic tools discovering the encrypted pictures within the sea of publicly shared images within the file sharing site or social media site that the system it using to store the file system.

There are many different kinds of steganographic techniques that assist in reducing the effectiveness of statistical analysis, recovery of data, and other methods of detection. [?] Other implementations of steganography do not use images at all, but rather encode data within other forms of media such as audio files or PDFs. Using a better steganographic technique in addition to encryption would increase confidentiality and plausible deniability [?].

The original Web-Based Covert File System Paper [1].

REFERENCES

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