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MAPPER: A Mobile Application Personal Policy Enforcement Router for Enterprise Networks

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***Abstract*—MAPPER is a system for enforcing user-specific policies based on the availability of access nodes that support the capability to dynamically load and execute processing modules on the data path. This work leverages a network access node that, after authenticating a connecting user, loads a set of lightweight virtual machines that process traffic terminated on the user device to implement articulated user-specific access policies. Specifically, we demonstrate how a man-in-the-middle-proxy module, dynamically and opportunistically combined with a module capable of mobile application identification, can implement complex access policies. The man-in-the-middle-proxy module enables MAPPER policies to be applied to both clear and HTTPS traffic, while an intelligent traffic classification system, provides support for policies based on over 250,000 mobile apps spanning both Android and iOS platforms.**

***Keywords*-network; policy; virtualization; apps;**

I. Introduction and Motivation

MAPPER (**M**obile **A**pplication **P**ersonal **P**olicy **E**nforcement **R**outer) is a network access point that, upon authenticating a connecting user, loads a set of modules to process network traffic to/from the user's device, and implements user-specific access policies based not only on content but also on the user applications that generate the traffic. This is in contrast to state-of-the-art firewall systems deployed within enterprise networks that rely largely on IP/domain-name/port based policy formulation and enforcement. Such conventional approaches are increasingly becoming untenable due to two primary reasons: (a) acceptance of user-owned devices (mostly smartphones and tablets) within enterprise networks (*a.k.a.* the bring-your-own-device to work phenomenon), and (b) the unprecedented proliferation of mobile applications (roughly 1.75 million for Android and iOS at last count). This poses new challenges on several fronts. First, a significant portion of the mobile applications use HTTP and HTTPS as the transport layer protocol, and are thus indistinguishable from the conventional *web-traffic*. The advent of Web 2.0, which facilitates rapid development of web-based and distributed applications, has only accentuated the problem. Second, while some applications (e.g. mail clients, calendars), may actually be useful to employees for their daily work and are hence a necessity; others, not equally benign, may compromise network and information security. Finally, the same application developed for different platforms (e.g. Android vs. iOS) or user-devices (e.g. Samsung Galaxy vs. HTC One) may have different security vulnerabilities. Therefore, for high resolution fine-grained traffic monitoring, provisions must be made to segregate application level traffic, originating from different user-devices and across platforms, effectively.

Next, and perhaps more importantly, there is the question of roles and privileges of individuals within an enterprise: not all employees are equals. While certain employees might need to access and/or share sensitive information with prospective clients for business objectives, others should not be permitted to do so. As mobile applications increasingly become multi-faceted and complex, such exfiltration risks have only escalated. For example, popular services such as Facebook, now function as authentication gateways and substrates for a large ecosystem of applications (e.g. FarmVille). This can provide indirect access to sensitive information to undesired, and potentially malicious, third parties. In view of these challenges, it is imperative that modern policy formulation and enforcement frameworks/systems have the capability to identify and differentiate traffic generated by different applications, across platforms and devices, and impose policies based on user roles, to guarantee network and information security.

MAPPER enables network administrators to formulate and enforce user/role specific policies within the enterprise network, at application as well as content level granularity, without requiring access to an end-user's device. User traffic segregation, for privacy and protection, is provided by allocating a user specific virtual machine, at the time of login, on a **FROG** (**F**lexible & p**ROG**rammable) network device [1], [2]. The user specific virtual machine runs *data plane applications* (*a.k.a.* net apps) that process, monitor, and filter the traffic associated with an individual user. MAPPER ensures that these net apps, as well as the policies they implement, persist seamlessly across network access points as the user moves within the enterprise. Similar migration is handled across multiple devices used by the same individual. A stand-alone module, interacting with the MAPPER system through a specific net app, handles mobile application identification and categorization [3]–[5]. Furthermore, by executing a man-in-the-middle proxy module [6], MAPPER also provides visibility into encrypted application traffic. Last but not least, MAPPER comes equipped with a simple yet flexible user-interface that enables a network administrator to define both the net apps and the corresponding policies for each user, cognizant of user-roles, applications, content, platforms and devices, in any combination.

II. System Architecture

MAPPER consists of the following modules that can be executed on a single host or distributed as needed on different ones, offering maximum flexibility in achieving the required scalability by duplicating any bottleneck module. The MAPPER architecture is depicted in Fig. 1.

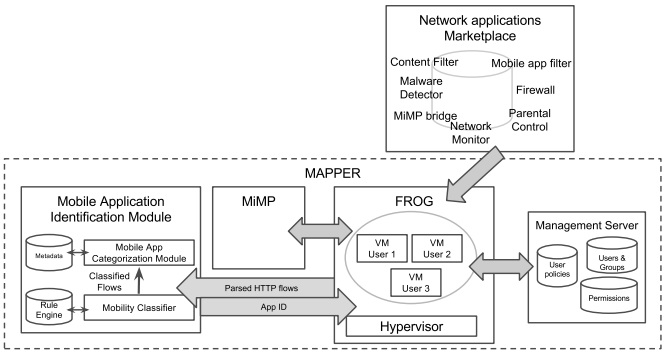

Figure 1. Mapper Architecture.

FROG [1]: A programmable edge router with integrated WiFi access point that supports per-user network function virtualization, which is used as a building block for user profile management. The network administrator can define net apps to be run and related policies for individual users or groups of users. A captive portal authenticates users at the time of their connection to the wireless LAN. Upon success, user profiles are loaded, i.e., net apps are downloaded from a net app marketplace, run and configured with the policies defined for the users. FROG allocates an exclusive virtual machine (VM) for each individual user to runs a chain of network apps (e.g. firewalls, network monitors etc). The network apps operate on every packet generated during a user's session. An obvious, and desirable, side-effect of such user level segregation is the privacy and protection of user data. Needless to say, it also simplifies the management process and forensics in the event of an anomaly. Finally, when a user authenticates with a different FROG device, MAPPER loads the same net app chain and policy configuration into the new FROG device, thereby providing the experience of them moving together with the user. Since this is true even when the user connects with a difference device, we can consider net apps and policies to migrate also across devices.

Mobile Application Identification Module [3]: A powerful application identification module capable of extracting and classifying network flows generated by over 250K mobile applications across the iOS and Android platforms. Moreover, this module provides device and platform information as well as application context in terms of category labels for each identified flow. The labels include app market, interest, and network function categories. This enables policy formulation at different granularity levels, whereby the network manager can white/blacklist individual mobile applications, devices, platforms or even broad categories.

Man-in-the-Middle Proxy (MiMP) [6]: A solution to provide visibility into encrypted application traffic by terminating HTTPS sessions from the clients within the wireless network and splicing them into HTTPS sessions to external hosts. Upon the first connection of a device, the user is required to install a certificate used for signing server certificates required by TLS to implement HTTPS. Although such practice might not be acceptable in general, we consider it acceptable in an enterprise scenario where MAPPER is operated under the supervision of the corporate network administrator.

Content Filtering: As an added dimension to policy definition, MAPPER enables keyword blacklisting in application content by means of a net app included in the profile of a user. This can be used in conjunction with application level policies, whereby a flow is considered inadmissible if it contains a blacklisted term, even if the application is allowed.

Policy Engine: By properly chaining net apps, MAPPER implements a simple yet modular policy engine that enables articulation of enforceable policies based on users, mobile applications, content, devices, and platforms, or any arbitrary combination thereof. An easy-to-use UI facilitates on-the-fly definition and modification of policies by the administrator. A full net app chain will include (*i*) a MiMP Bridge net app to divert traffic to the MiMP module and then insert it back in the net app chain, (*ii*) a Mobile Application Filter net app to send relevant parts of the traffic to the Mobile Application Identification Module, receive back information on the mobile app generating the traffic, and then verify its compliance with the user-specific policy, and (*iii*) a Content Filter net app to check compliance to the content policy.

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