A Trustworthy Middlebox-aware Networking Architecture

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1 Motivation

Using TLS middleboxes (a.k.a. TLS proxies) has been problematic since splitting TLS connections in a “middlebox-in-the-middle” fashion is risky \cite{2, 3}. Currently, a TLS middlebox makes a TLS connection split (so, called \textit{split TLS}) to perform its functionality in-between two endpoints. In particular, it intercepts a client’s \texttt{ClientHello} addressed to the intended server and plays the role of the server by performing a TLS handshake with the client. For this purpose, a client-side middlebox (e.g. an anti-virus software) uses a forged certificate (of the intended server) signed by the custom root certificate pre-installed on the client. Similarly, a server-side middlebox (e.g. a website application firewall) uses a certificate taken from the server for impersonation. In any case, a middlebox sends a \texttt{ClientHello} to the server, which initiates another TLS handshake between the middlebox and the intended server. The number of split TLS sessions can be more than two since there can be multiple middleboxes between the client and the server.

Figure 1: A middlebox, such as an anti-virus software, splits TLS into two separate TLS sessions, impersonating the server in the middle of the client and the server.

Although the \textit{split TLS} approach (as in Figure 1) helps a middlebox intervene and process data on-the-fly, it breaks the security requirements of TLS: entity authentication, data secrecy, and data authentication. For instance, from a client’s standpoint, data is encrypted only between the client and the next middlebox; she has no idea of whether her data will have confidentiality and integrity after the next middlebox. Also, she cannot be assured of the authenticity of the intended server.

Thus, the client is forced to trust the “secure” indicator on her browser, even if the security is broken after the next middlebox. We seek to address this problem by making her explicitly aware of TLS interception \cite{9}. After she becomes aware of the middleboxes, there should be a mechanism to manage the trustworthiness of the middleboxes.

There are several studies related to this issue \cite{1, 4, 7, 8, 10}. All the proposals have been discussing either a certificate for a middlebox or a secure participation of a middlebox in TLS. Less attention, however, has been paid to how to address both issues together.

2 Middlebox-aware Architecture

Figure 2: Our architecture seeks to ensure end-to-end secure connections through explicit authentication and modification check of each middlebox.

To this end, we propose a trustworthy middlebox-aware networking architecture as in Figure 2. The key concept of the architecture is trustworthiness management of middleboxes, which is substantiated by extending TLS in a middlebox-aware fashion (dubbed maTLS).

We define the trustworthiness of a middlebox as \textit{public auditability}. Thus, trustworthiness management is a way to make a middlebox auditable in terms of its certificate and its read/write permission. This is feasible by introducing two mechanisms: (i) explicit authentication of a middlebox by its certificate, and (ii) permission check on a packet modification by a middlebox.

Explicit authentication: Every middlebox has its certificate that lists its publisher, its role, its read/write permission, and other fields. A certificate authority issues a middlebox certificate to a middlebox publisher and logs the certificate in a ‘middlebox transparency,’ which is audited by a middlebox auditor. (Note that the middlebox transparency is similar to the certificate transparency \cite{5}.)

Modification check: In the maTLS protocol, whenever a participating middlebox modifies a packet, it records this operation by adding a message authentica-
anition code (using a key established during the maTLS handshake). From the record of packet modifications, the client figures out all intermediate writers and detects invalid modifications by cross-checking the permission information in their certificates. The client may report invalid modifications to the auditor via an out-of-band channel. The auditor checks the corresponding certificate for the invalid modification, whose result is notified to the middlebox publisher and the certificate authority.

3 Future Work

To demonstrate the feasibility of our architecture, we plan to perform two main tasks: formal verification and evaluation. We will prove the security of maTLS with the state-of-the-art formal verification tool Tamarin [6]. This will improve our protocol by identifying any security flaws based on the security requirements. Further, we will implement our architecture in C with the OpenSSL library and evaluate the performance overhead in terms of delay and memory usage of participating parties.

4 Conclusions

In this proposal, we design a trustworthy middlebox-aware networking architecture, whose main concept is the trustworthiness management of middleboxes in an open fashion. By verifying their certificates and read/write permission, the proposed architecture can enhance the security of end-to-end TLS communications in presence of middleboxes.

References