ECSE 414 Intro. to Telecom. Networks
Deliverable #1 - Description

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Methodology

The Onion Routing protocol will be implemented with several independent routers that will be referred to as nodes that communicate via TCP and HTTP packets. Each node has a key pair that can be used to implement asymmetric cryptography. Additionally, there will be a special server called the Directory Node. This Directory Node contains a set of all n node address and public key pairs: $\{(a_i, p_i)|0 \leq i < n\}$, where a_i, p_i are the address and public key corresponding to node i, respectively.

Say a sender $\mathcal{S}$ wishes to send a request (and receive a response) from some destination $\mathcal{D}$. Firstly, $\mathcal{S}$ establishes a TCP connection to the Directory Node, which generates a random path of nodes through which $\mathcal{S}$ will send his message. For each node n_i in the list, the Directory Node negotiates with the corresponding p_i, thereby producing symmetric keys s_i for each intermediate node. The Directory Node then constructs a packet containing $\{(a_i, s_i), n_i \in \textbf{path}\}$ and encrypts it with the public key corresponding to $\mathcal{S}$, and sends the cipher to $\mathcal{S}$.

Now, $\mathcal{S}$ can decrypt the cipher with his private key. He creates the request he wishes to send to $\mathcal{D}$, and encrypts with each s_i successively, in reverse order (so the first s_i he encrypts with corresponds to the last node in the path). Before encrypting with each s_i, a header indicating which node to send to next is prepended so that each node can determine where to send the packet after decrypting. The sender proceeds to send this cipher to the first node in the path.

Each intermediate node behaves according to the exact same protocol. Upon receiving a packet, an intermediate node n_i can decrypt the packet with its symmetric key, and can determine the node n_{i-1} immediately before it in the path. Upon decrypting, the node can read the address of the next node n_{i+1} in the path, and sends the packet to n_{i+1}. Then, the node waits for a response packet. Upon receiving the response packet, n_i encrypts the response with s_i and sends the packet to n_{i-1}. When $\mathcal{S}$ receives the response, he may decrypt with each symmetric key successively, and can then read the response.

The node servers (and Directory Node server) will be programmed with the Python programming language, and will use the Flask framework to handle concurrent requests. The Vagrant tool will be used to automate the creation of virtual machines which will simulate the nodes. Additionally, to save processing power, the Directory Node will run locally on the sender's machine for the purposes of the simulation.

Furthermore, the NTRU cryptoscheme will be considered and investigated to provide key exchange for communicating the s_i keys, and can maintain security against quantum opponents.

Testing

The goal of the project is to achieve a minimalist implementation of onion routing and perform analysis of its performance via simulation. As such, testing of this project should be divided into two sections:

1. **Verify and validate the onion routing implementation:** We will follow a Test Driven De-

velopment (TDD) paradigm. Writing test cases first, then deriving the unit tests through equivalence partitioning and finally writing the necessary code for all the tests to pass. Throughout this iterative process we will rely on Continuous Integration (CI) to efficiently manage all the source code generated by each sub-team. The concept of pair programming will be leveraged in order to equally subdivide the tasks among the group and to ensure regular code reviews are performed on the code base. With respect to the application testing, we shall focus on three main aspects of onion routing: bidirectional communication, encryption of data through nodes and randomized path selection. Each of these characteristics will be unit tested with virtual machines and after satisfying our requirements they will be undergo integration testing. In order to efficiently replicate the development and testing environment across the machines of each team member, Vagrant will be used to build and maintain the portable virtual development environments.

2. **Analyze the performance of the application through simulation:** There will be two tools that will be used, one is Nmap which provides a broader overview of the network and Wireshark to examine the packets transferred between nodes. We will be using Nmap for testing enumeration of network components and available application layer protocols at end hosts. It will also be used to identify any vulnerabilities in the network and to ensure the ports are connected to the correct hosts. Wireshark is used to test encryption requirements, provide an analysis of the chosen network and ensure contiguous nodes know the adjacent source destination and not the global ones. For further testing, we may use the mentioned tools such as Brite or Orbis to generate network topology to simulate characteristics in the internet.

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