Poster: Taming Asymmetric Delays for Network Time Protocol Using Electric Grid Frequency

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1. INTRODUCTION

Time synchronization is crucial to many distributed applications. Network Time Protocol (NTP) is a widely adopted time synchronization protocol. To synchronize a master and slave accurately, NTP measures the round-trip time (RTT) of a synchronization packet between them. It assumes that the two one-way transmission delays are equal. Thus, by measuring the RTT, NTP calibrates the slave's clock based on the sum of the master's clock value in the synchronization packet and RTT/2. However, this symmetric delay assumption may not hold in practice, due to asymmetric network paths or malicious network transmission delays introduced by an attacker. This abstract presents a new time synchronization protocol, which we call *Grid Time Protocol* (GTP), that utilizes an alternating current (ac) electrical grid's voltage signal as a reliable and extrinsic time source to measure asymmetric delays individually, thereby achieving resilient time synchronization between a master and slave connected to the same grid.

2. APPROACH

GTP works by leveraging the 50/60 Hz electrical grid frequency, a highly accessible and reliable reference signal that is hard for the adversary to compromise. Between two geographically distant locations within the same grid, the voltage oscillates uniformly with a near-constant phase shift. Thus, by observing the phase angle of the reference voltage when a GTP slave/master sends/receives a synchronization packet, we can accurately estimate the communication delay between the two nodes. GTP uses an ac-ac voltage adaptor to capture the reference voltage signal. The analog output of the adaptor is fed to a computer's sound card for digitization via a line-in port. This reference implementation requires little effort to retrofit COTS computers to run GTP. An example deployment of GTP is illustrated in Fig. 1. A user program records the digitized data from the line-in port. The sinusoidal signals represent the reference voltage signals seen respectively by the slave and the master.

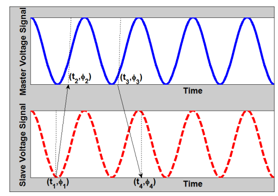

Figure 1: GTP Illustration.

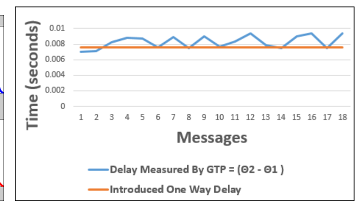

Figure 2: GTP Evaluation.

These signals were captured from two different locations approximately 30 kilometers apart in Singapore. The voltage signals observed by the master and slave have almost the same phase angle. For time synchronization, the slave sends a `sync` request to the master, which contains the phase angle (Φ_1) of the reference voltage signal and the slave's clock (t_1) at the time of sending the request. When the master receives the `sync` request, it computes the current phase angle of its reference voltage signal (Φ_2) and its current clock (t_2). The phase shift $\Theta_1 = \Phi_2 - \Phi_1$ corresponds to the `sync` packet's transmission delay from the slave to the master. Similarly, the master constructs a reply packet to each request. This packet contains the phase angle at the time of receiving the `sync` request packet (Φ_2), the current phase angle when sending the reply packet (Φ_3), the master's clock at the time of receiving the `sync` request (t_2), and the current clock when sending the reply (t_3). When the slave receives the reply, it computes the current phase angle (Φ_4) and records its current clock (t_4). The transmission delay of the reply packet corresponds to the phase shift $\Theta_2 = \Phi_4 - \Phi_3$. Thus, GTP can measure the two one-way delays individually, thereby removing the symmetric delay assumption, which can be vulnerable to attack.

3. IMPLEMENTATION AND EVALUATION

To measure the accuracy of GTP in calculating asymmetric links, we set up a GTP slave and master. Both nodes run Windows OS, and are equipped with GTP hardware. To mimic a delay attack, a delay of 7.5 ms was deliberately added to the reply messages of GTP. The difference between the slave-to-master (Θ_1) and master-to-slave (Θ_2) communication time should give the added one-way delay, i.e., 7.5 ms. As illustrated in Fig. 2, the average delay difference measured by GTP is 8 ms. Thus, we conclude that GTP can measure asymmetric communication links between two nodes with high accuracy.

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