A TSCS PROPERTIES

A.1 Guaranteeing TSCs

TSCS ensures each client receives usage according to its TSC.

Theorem 1. *TSCS ensures that each client receives dominant item usage according to its transactional service curve.*

Proof. Consider a system with a fixed number of clients. Without loss of generality, we assume that all clients are active during an interval $[t_1, t_2)$. Let us say that all clients start with the same virtual time at the beginning of the backlogged interval. By design, TSCS equalizes client virtual times. Virtual time is determined by the dominant item usage by each transaction via the virtual curve (Section 5.1). For a given client c that executes transaction $T_{c,j}$ at time t, let us say its dominant item usage is $u_c(T_{c,j})$. Accordingly, the total service of this client $w_c(t)$ will increase by $u_c(T_{c,j})$. The client's virtual time is then determined by $v_c = V^{-1}(a_c^k; w_c)$ at t, reflecting the dominant item usage for this transaction. Thus, each client's virtual time increases with its dominant usage and the virtual curve is constructed according to each client's TSC, the service of every client will follow its transactional service curve. □

A.2 Strategy-Proofness

Theorem 2. *SCT ensures strategy-proofness (a client cannot increase its dominant resource usage by lying about its demand, i.e., by adding extraneous operations and/or transactions).*

Proof. We consider three cases: (i) linear, (ii) concave, and (iii) convex transactional service curves. We assume that the concave service curve has slope β followed by α, where $\beta > \alpha$, while the convex service curve has slope α followed by slope β.

For case (i), using TSCS with a linear service curve is equivalent to using DRFT with the same weight as the slope of the service curve. This follows from the design of DRFT [16]: a client cannot increase its own usage by causing contention with others because its own usage will also increase.

For case (ii), we prove by contradiction that a client cannot have better service by lying about its demand. Since a client cannot increase its use usage by adding extraneous operations/transactions, the only thing it can lie about is when it wants to send its requests. Namely, the client can delay its requests in hope of staying in the higher service regime of the service curve (slope β), assuming it is currently in the lower service regime (slope α). Specifically, we assume that t is the inflection point of the service curve and t' is the current time, where $t' > t$. Thus, the client would need to delay its requests by at least $t' - t$ to get to the higher service regime. However, delaying these requests would not help the client because when the client returns from being idle, its virtual curve is updated according to the minimum of the previous curve and a new base TSC (Section 5.1). Thus, it cannot get more service than if it were continuously backlogged, which is a contradiction.

For case (iii), we prove that a client cannot skip past the lower service regime (slope α) to get to the higher service regime of the service curve (slope β) prematurely. TSCS models each client's virtual curve after its TSC, so the convex service curve would be reflected in its virtual curve. As each transaction executives, TSCS accounts for client service based on dominant usage and determines the virtual time accordingly. As such, there is no way to the client to skip past the lower service regime (slope α). Even if it becomes idle, the virtual curve will be reset the minimum of the previous curve and a new base TSC (that starts with the lower service regime). □