RANDOM BROADCAST BASED DISTRIBUTED CONSENSUS CLOCK SYNCHRONIZATION FOR MOBILE NETWORKS

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OBJECTIVE

- Bring all virtual clocks to a consensus via a linear function of the nodes' own local clocks.

PROBLEM FORMULATION

- $T_i(t) = f_i t + \theta_i$ → Absolute time representation

  Where T_i represents the local time of node i, f_i represents the rate of node i, and θ_i represents the offset of node i.

- $C_i(t) = \alpha_i T_i(t) + \beta_i = \alpha_i f_i t + \alpha_i \theta_i + \beta_i = \hat{f}_i t + \hat{\theta}_i$ → Virtual clock estimation as a linear function

  Where $\hat{f}_\mathrm{i}$ represents virtual clock frequency estimate and $\hat{\theta}_i$ represents virtual clock offset estimate.

SOLUTION: RBDS SCHEME

- Suppose node i receives a timing message at the time $t_\ell + \delta_\ell$. Here, t_ℓ is the perfect time when the message was sent during the ℓth SR and δ_ℓ is the transmission delay, which includes the PHY layer delay and the propagation delay.
- We denote the transmitting node by $\widetilde{j(\ell)}$. Hence, the received time stamp at the time $t_\ell + \delta_\ell$ is $C_{\widetilde{j(\ell)}}(t_\ell)$.
- Next we present the two update rules.

PARTIAL UPDATE RULE

- The aim of the partial update rule at time t_ℓ is to achieve the update (1) when $\hat{\hat{f}}_{\tilde{j}(\ell)} = \hat{f}_i^{(\ell)}$ which implies that:

$$\hat{\theta}_i^{\ell+1} = \frac{1}{2}\left(\hat{\hat{\theta}}_{\tilde{j}(\ell)} + \hat{\theta}_i^{\ell}\right) + \frac{1}{2}\left(\hat{\hat{f}}_{\tilde{j}(\ell)} - \hat{f}_i^{(\ell)}\right) t_\ell$$

COMPLETE UPDATE RULE

- Suppose node i receives a timestamp from node $j = \tilde{j}(\ell)$ at time t_ℓ . Furthermore, suppose the last time node i received a timestamp from node j was t_n. Hence $t_n < t_\ell$ and $j = \tilde{j}(\ell) = \tilde{j}(n)$. Node i will perform a complete update if the following two conditions are satisfied
- a) Node j has not performed a **partial** or **complete update** in the interval $(t_n, t_\ell]$.
- b) Node i has not performed a **complete update** in the interval $(t_n, t_\ell]$.

Update (1) : $\hat{\theta}_i^{\ell+1} = \frac{1}{2}\left(\hat{\theta}_i^{\ell} + \hat{\theta}_j^{\ell}\right)$

- From Fig.1, it is clear that:

$$\frac{\hat{f}_j}{\hat{f}_i^{(\ell)}} = \frac{C_j(t_\ell)-C_j(t_n)}{C_i(t_\ell)-\sum_{m=n}^{l-1}\Delta_i^{(m)}-C_i(t_n)} \text{ where } \Delta_i^{(\ell)} = \frac{1}{2}\left(C_j(t_\ell) - C_i(t_\ell)\right)$$

Therefore, α_i and β_i get updated as following:

$$\alpha_i^{(\ell+1)} = \frac{1}{2}\alpha_i^{(\ell)}\left(1 + \frac{\hat{f}_j}{\hat{f}_i^{(\ell)}}\right)$$

$$\beta_i^{(\ell+1)} = \frac{1}{2}\left(C_j(t_\ell) - \frac{\hat{f}_j}{\hat{f}_i^{(\ell)}}C_i(t_\ell)\right) + \frac{1}{2}\left(1 + \frac{\hat{f}_j}{\hat{f}_i^{(\ell)}}\right)\beta_i^{(\ell)}$$

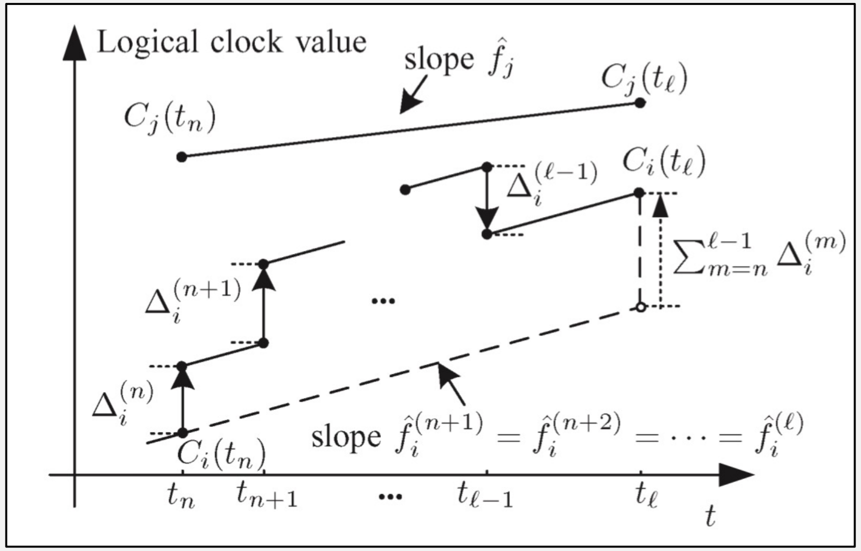


Fig. 1: Evolution of a logical clock

RESULTS (10 NODES)

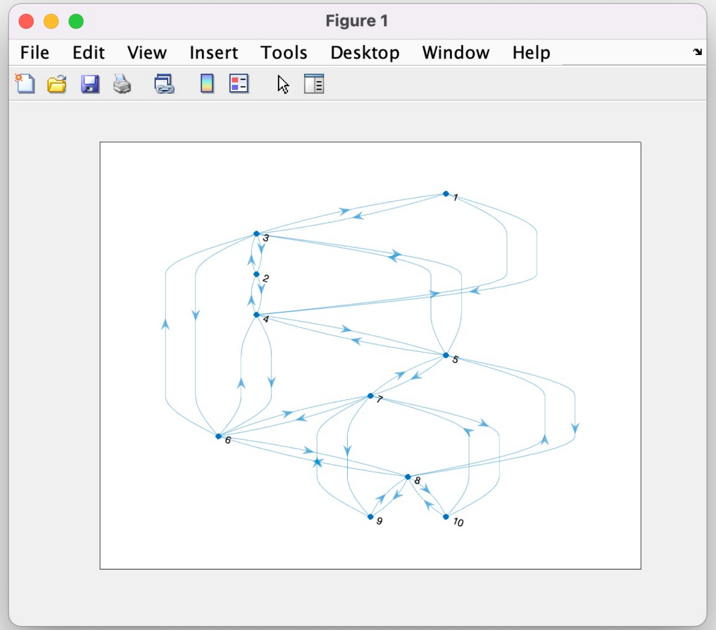
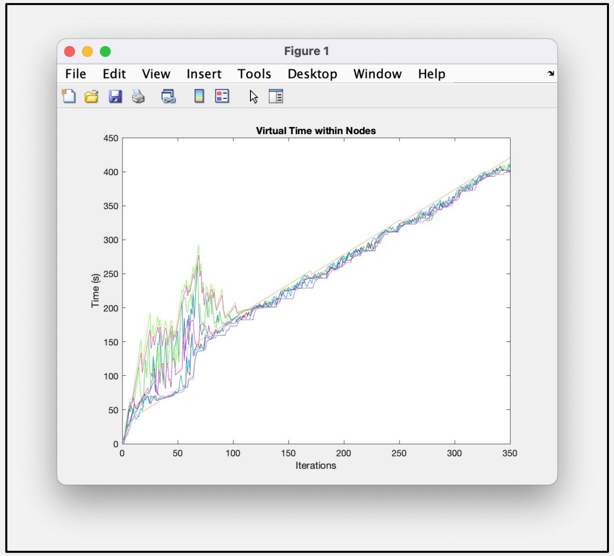
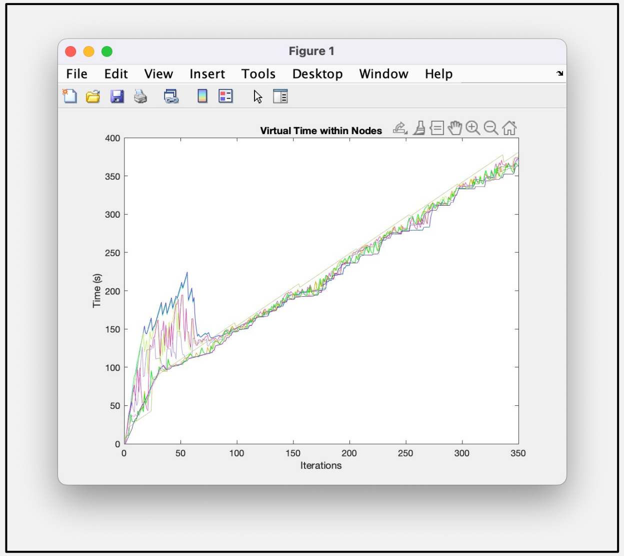


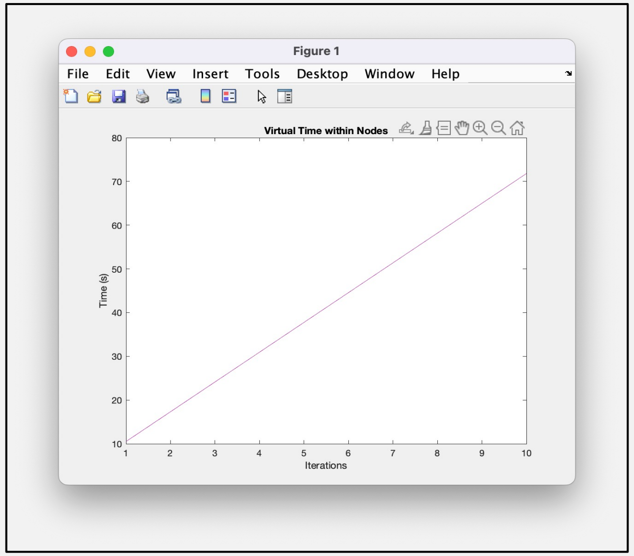
Fig. 2: Node connections



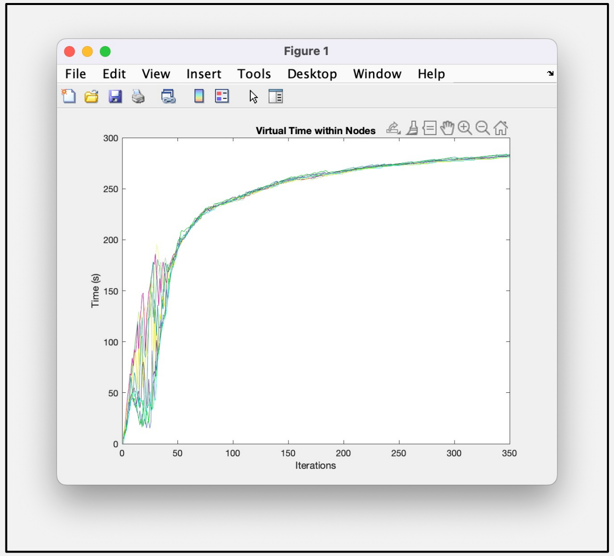
Strongly connected
Consumed time: 0.022423 secs



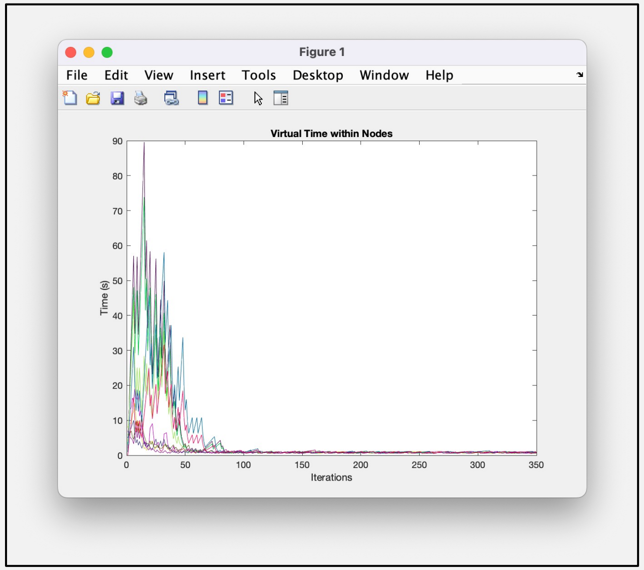
Periodically Strongly connected
Consumed time: 0.031185 secs



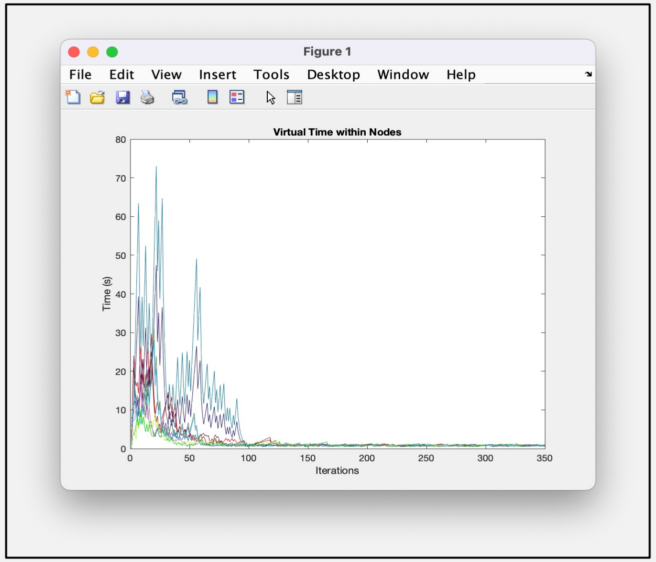
Centralized
Consumed time: 0.001173 secs



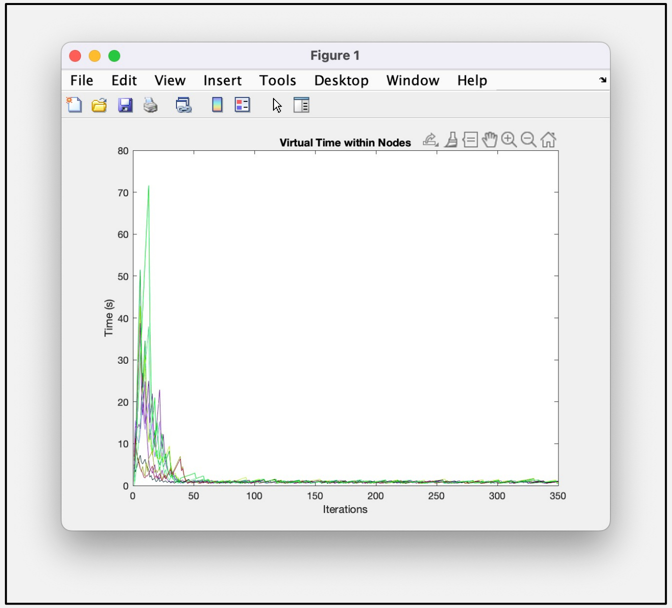
Asynchronous Gossip Scheme
Consumed time: 0.074220 secs



Stochastic metrics
Consumed time: 0.027255 secs



Varying stochastic metrics
Consumed time: 0.082036 secs



Doubly Stochastic Matrix
Consumed time: 0.020477 secs