# Efficient Time Synchronization in WSNs by Adaptive Value Tracking

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# Outline

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- Read-only ***Hardware clock*** $H(t)$ frequently **drifts** apart ($\pm 100$ ppm)
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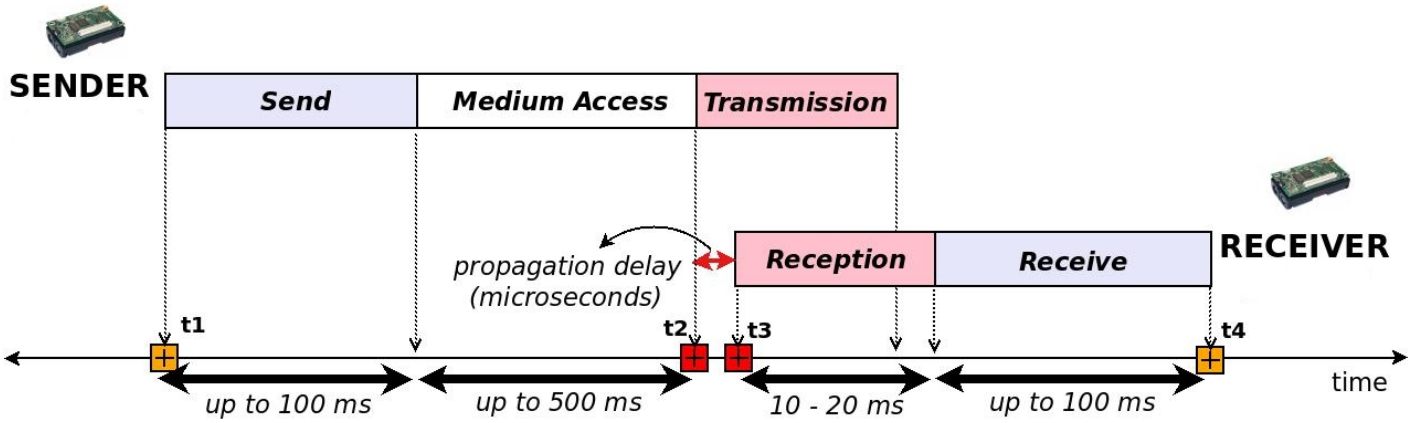

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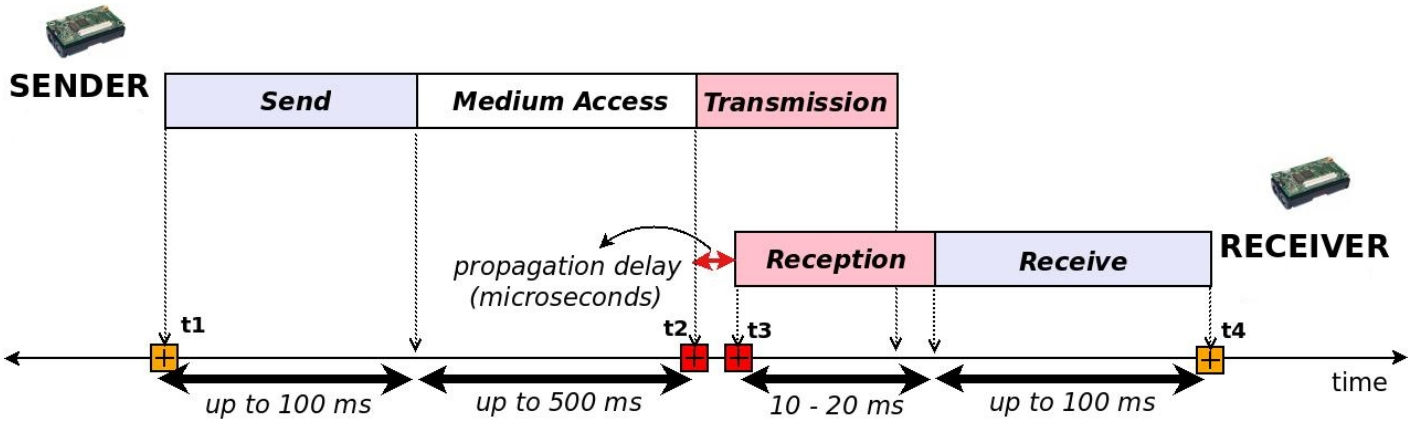


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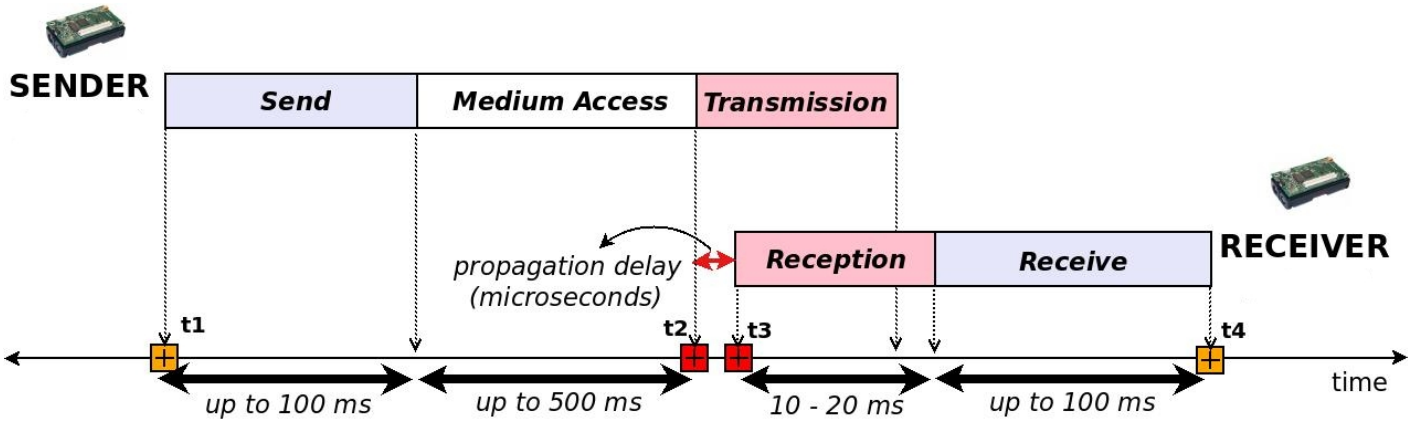


## Participate in *time synchronization*

- exchange current time information periodically (e.g. hw clock value)
- calculate a ***logical clock*** $L(t)$ (represents the **common time**).
  - $\frac{dL(t)}{dt} = h(t)l(t)$ :***rate multiplier*** of $L$.

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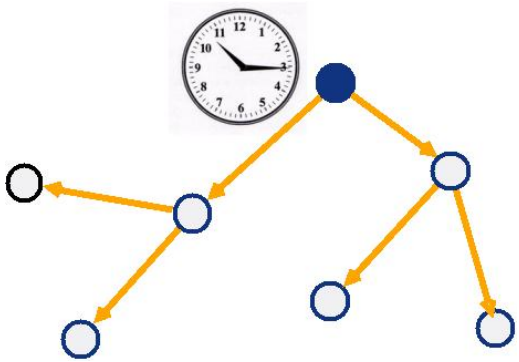

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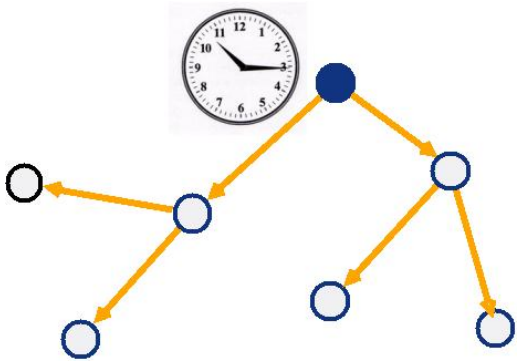

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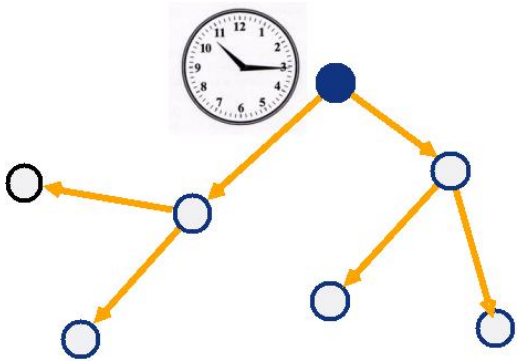

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  - **predict** future time - without communicating frequently
  - broadcast clock values - **network-wide synchronization**
- Minimize ***clock skew*** (*synchronization error*) at any time instant
  - **Global Skew** - skew between **arbitrary** nodes - **MAIN GOAL!**

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  - **poor synchronization performance - FTSP** [Maróti et al., 2004]
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  - **keeping track** of the neighboring nodes **- FCSA** [Yildirim and Kantarci, 2013]
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Is it possible to achieve high quality time synchronization **without having these drawbacks**?

- We introduce a new time synchronization protocol whose main component is **adaptive-value tracking - AVTS protocol**
  - identical synchronization with an approximately **97% less CPU overhead** and **80% less memory allocation**

# Outline

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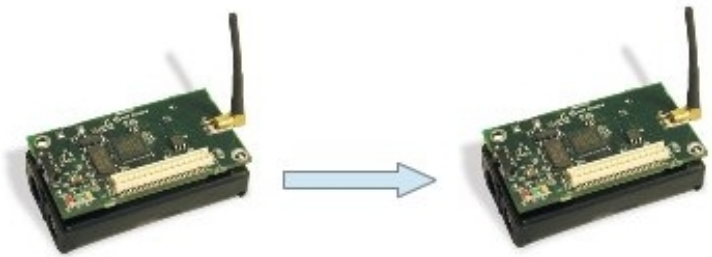
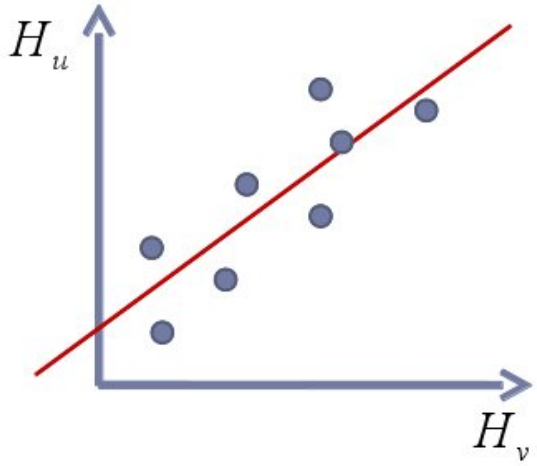


- ***Send*** time $t_1$: $\boxed{H_u(t_1)}$
- ***Receive*** time $t_2$:
  $\boxed{H_v(t_2), \hat{H}_u(t_2)}$

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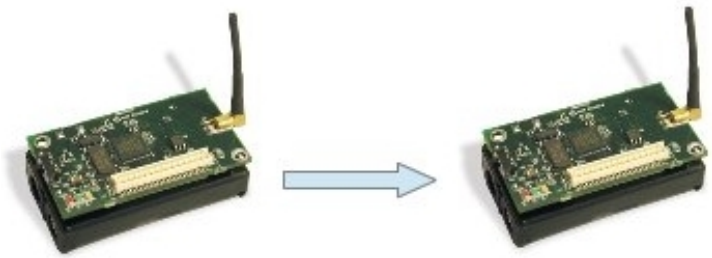

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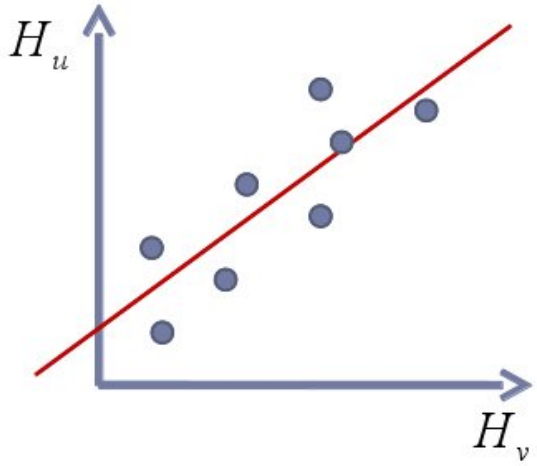


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## Least-squares line

- ***Linear relationship*** is modeled as $Y_i = \alpha + \beta x_i + \varepsilon_i \sim \mathcal{N}(\mu, \sigma^2)$

- **Logical Clock** $L_v = \hat{\alpha} + \hat{\beta} H_v$
  - $\hat{\beta} = \frac{h_u}{h_v} = \frac{\sum(x_i - \bar{x})(Y_i - \bar{Y})}{\sum(x_i - \bar{x})^2}$ - **rate multiplier**
  - $\hat{\alpha} = \overline{Y} - \hat{\beta}\overline{x}$ - **offset**

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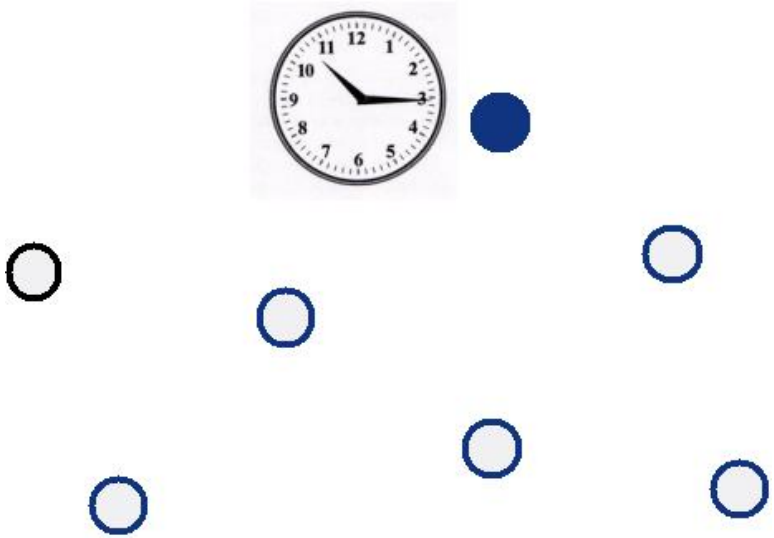

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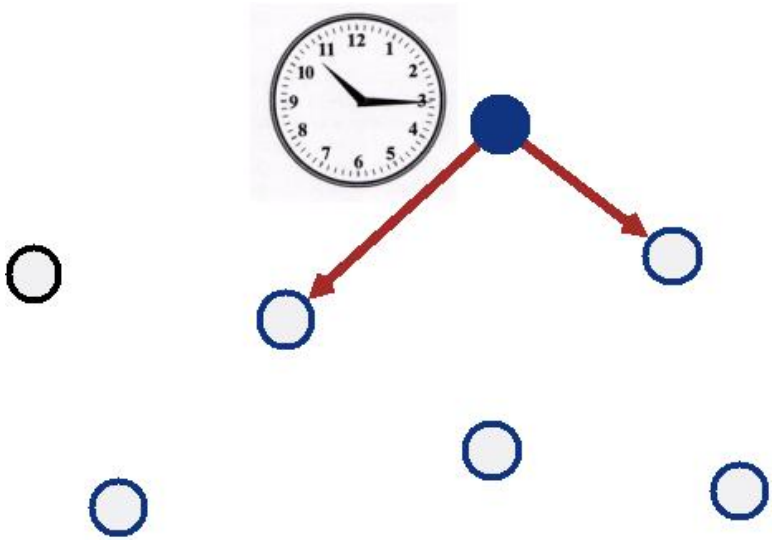

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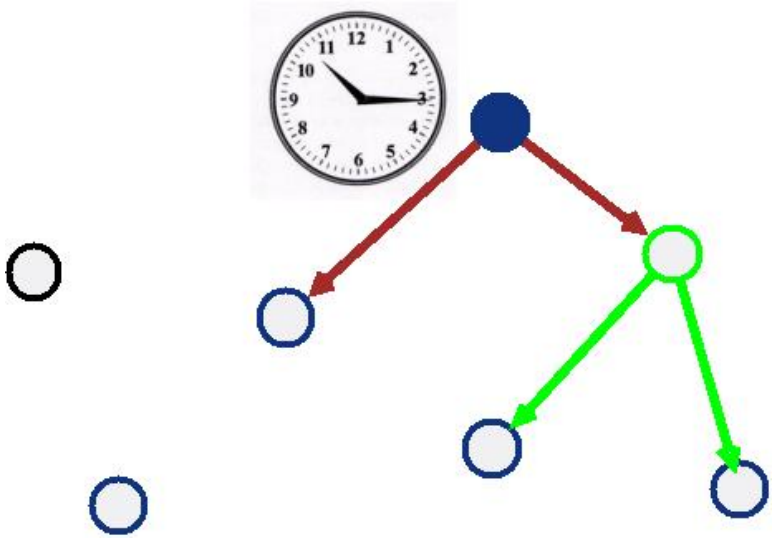

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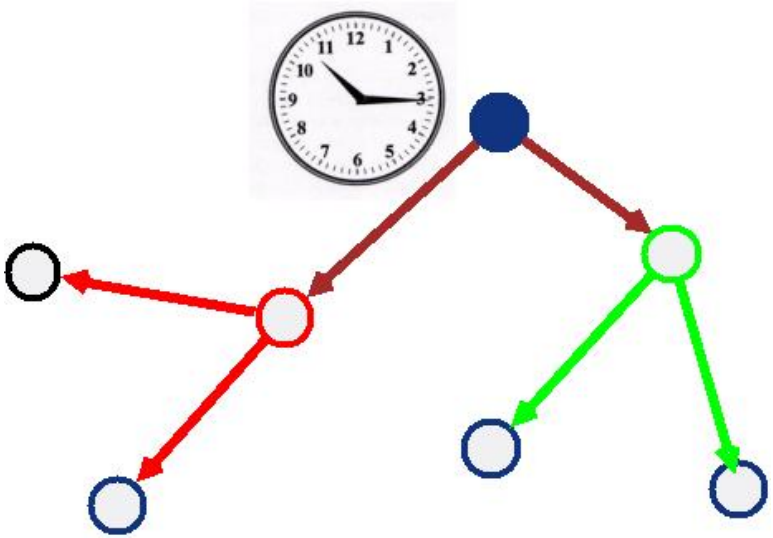

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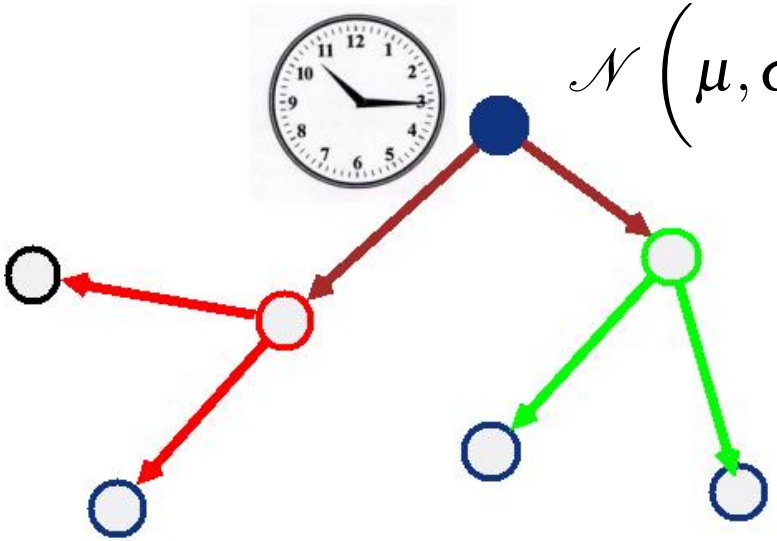

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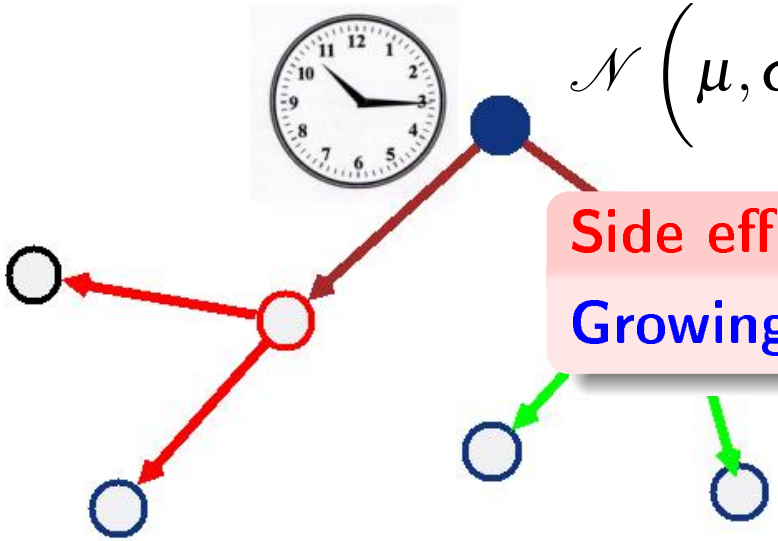

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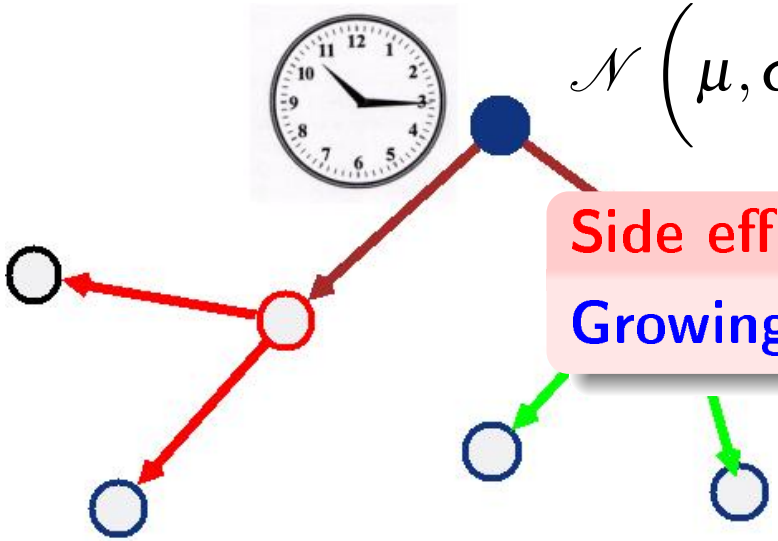

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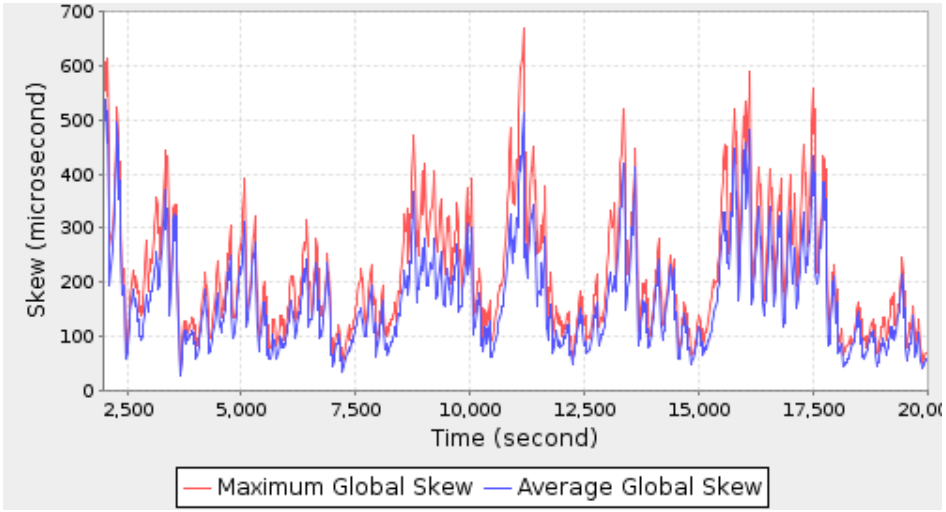


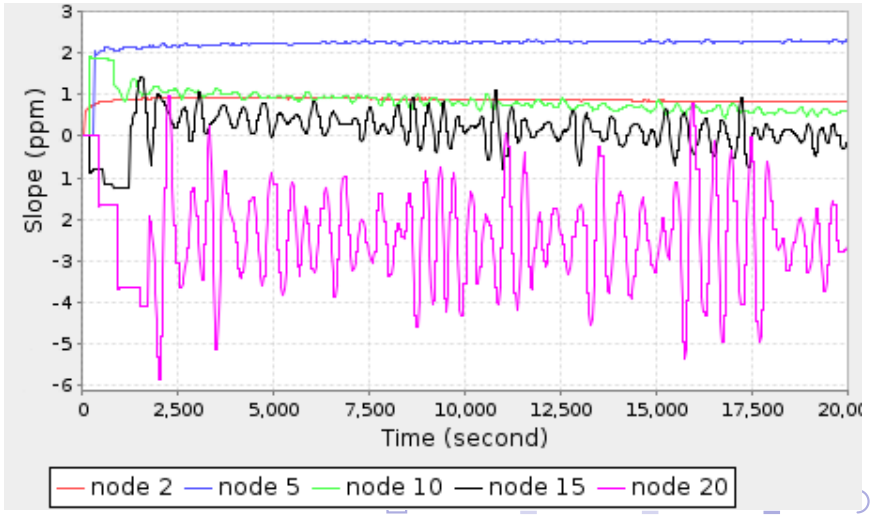

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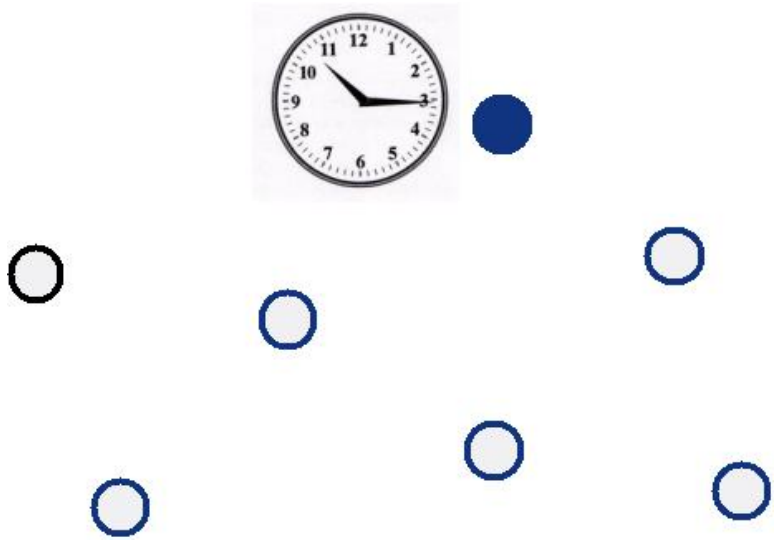

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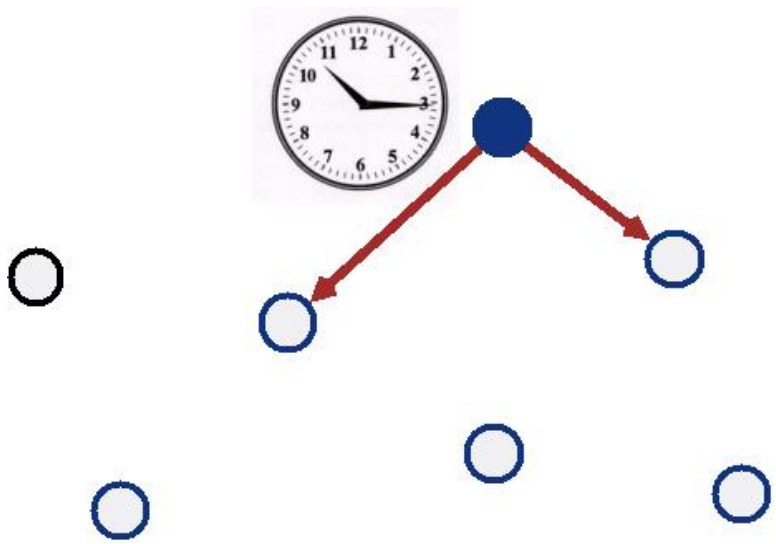

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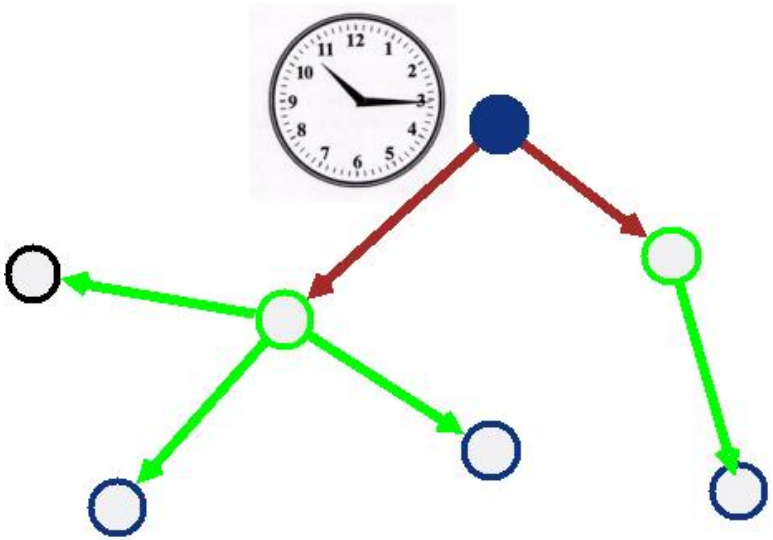

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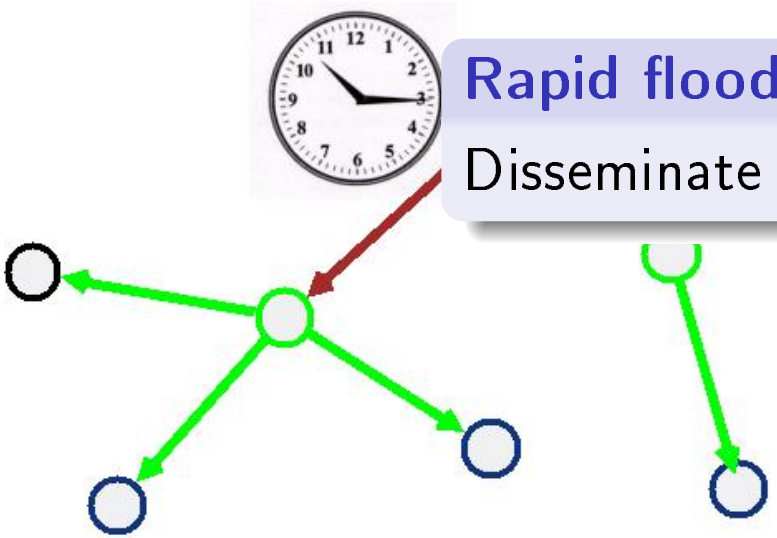

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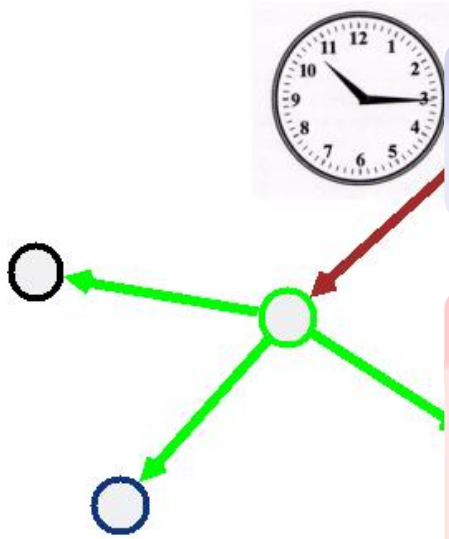

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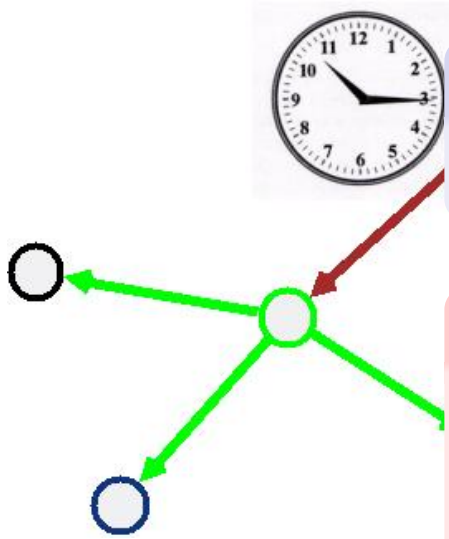

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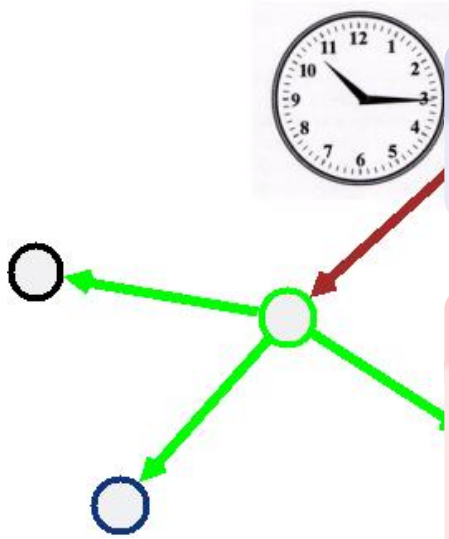

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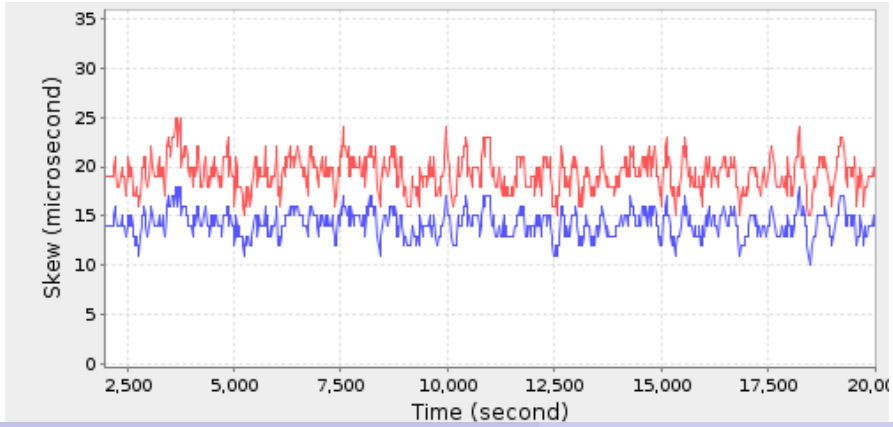


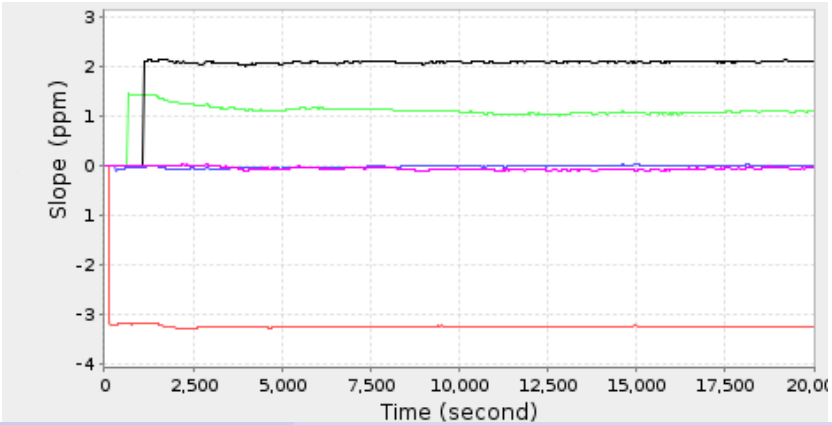

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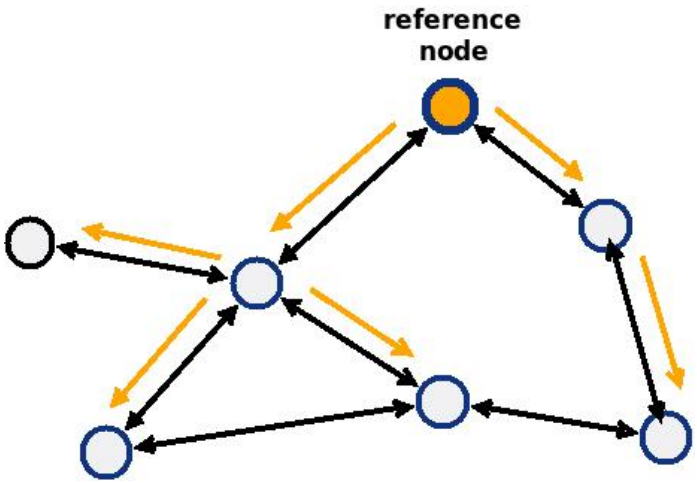

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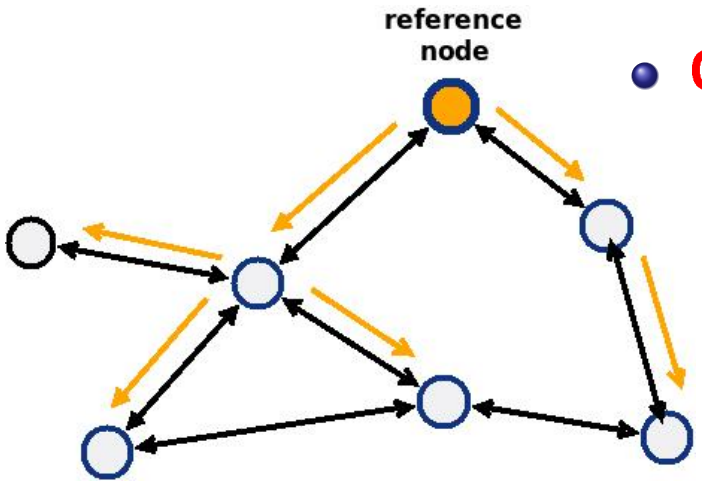


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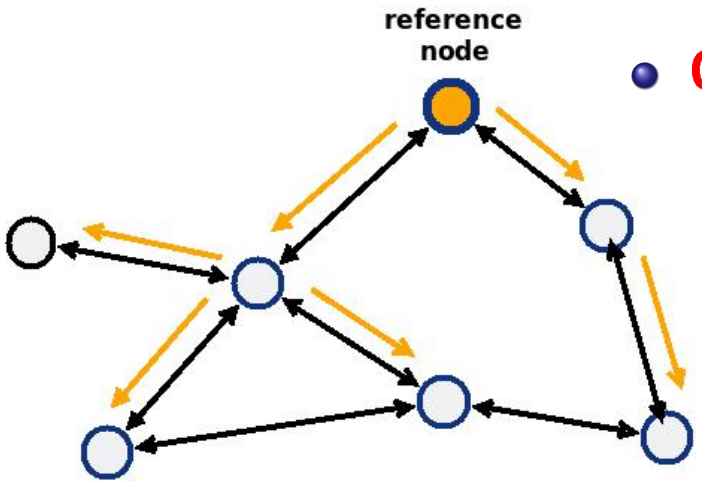


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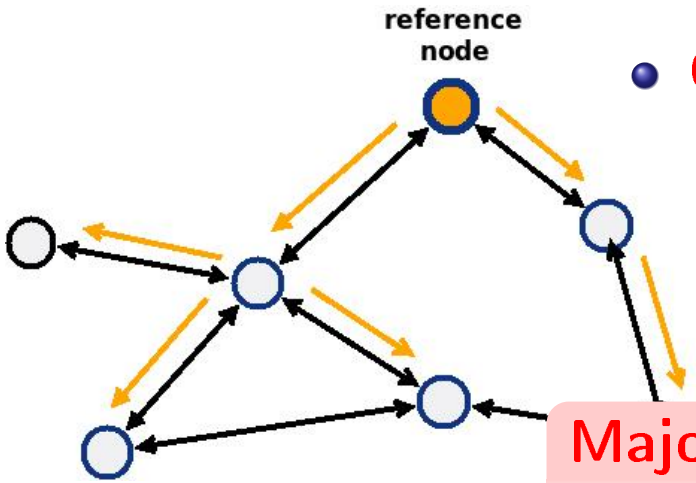


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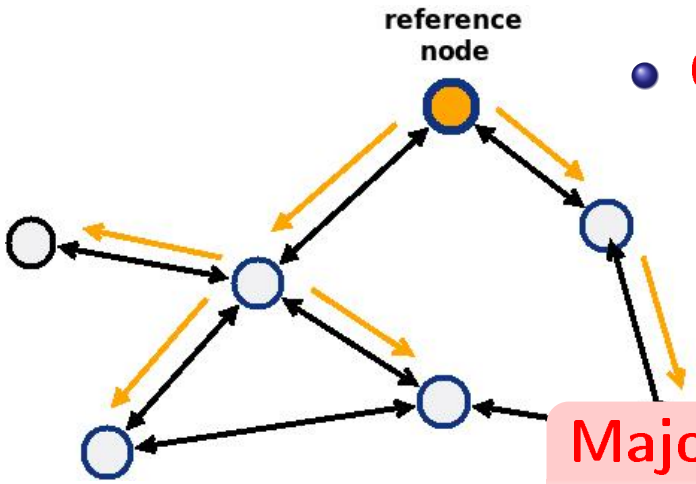


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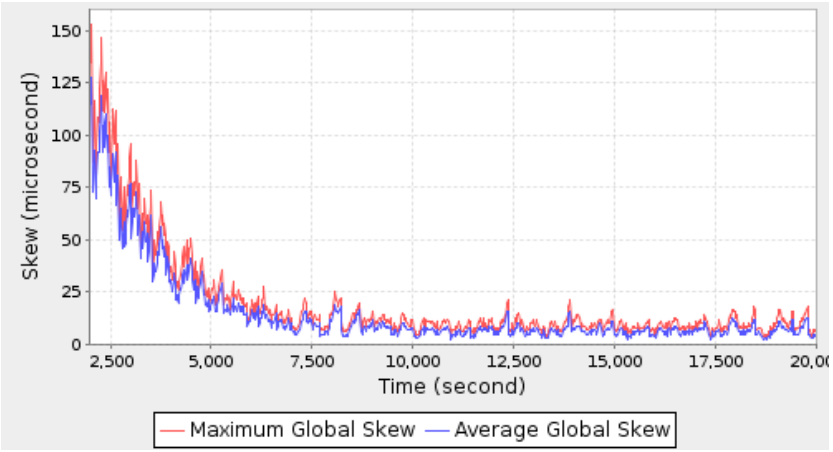


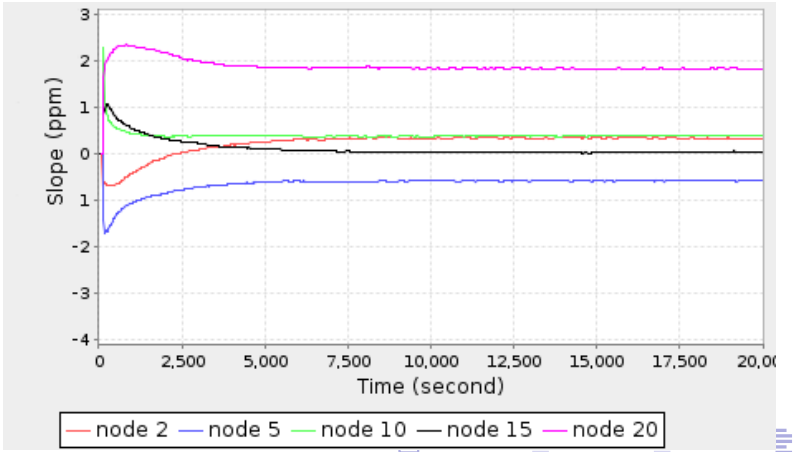

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  - proposes a ***value*** $v_t \in AVT_{ss}$ to its **environment**: $v_t = avt.value(t)$ at any time t

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## Next step proposed value

$$v_{t+1} = \begin{cases} v_t + \Delta_{t+1}, & f_{v_t} = f \uparrow \\ v_t - \Delta_{t+1}, & f_{v_t} = f \downarrow \\ v_t, & f_{v_t} = f \approx \end{cases}$$

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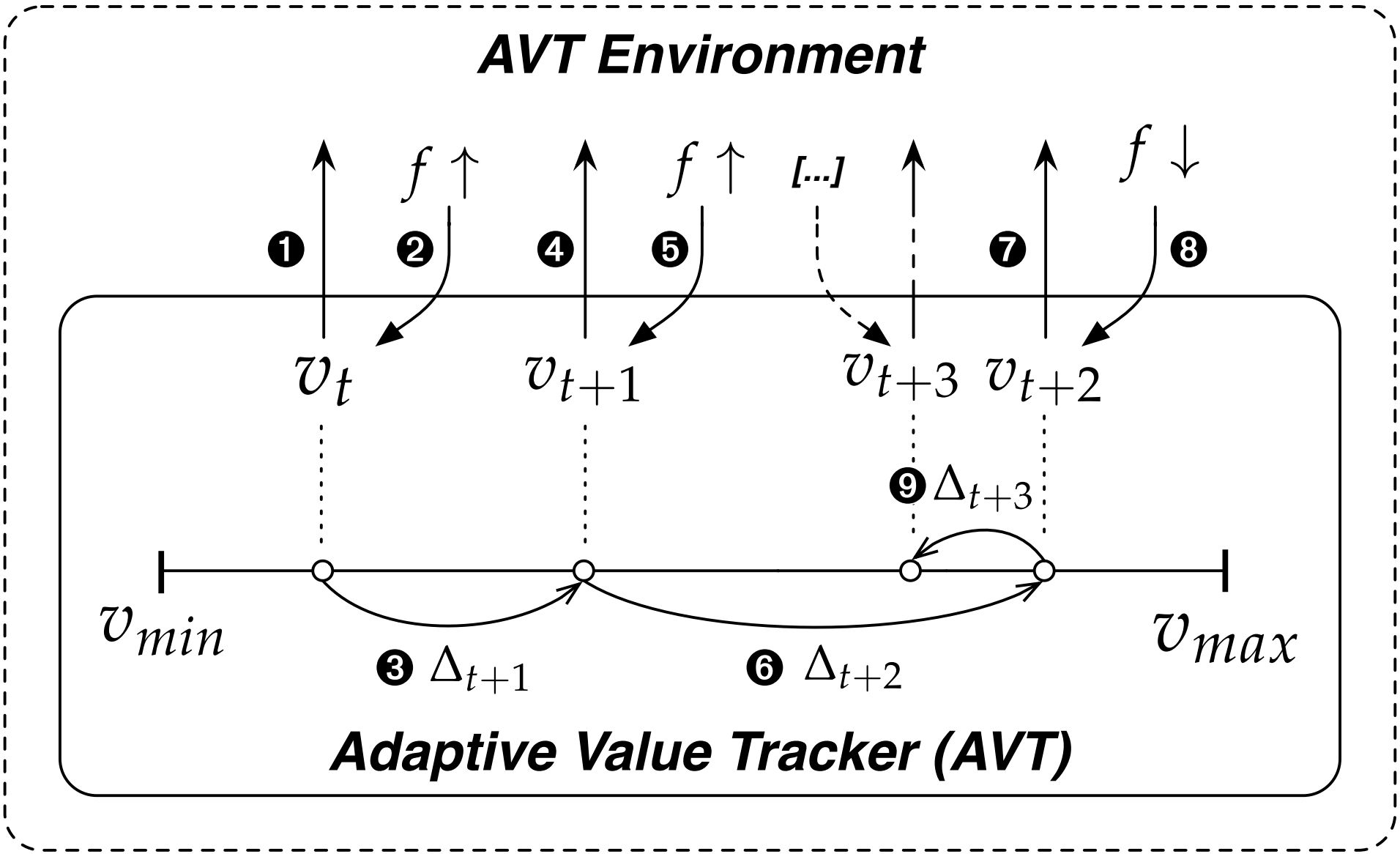
# AVT and Environment - Interaction



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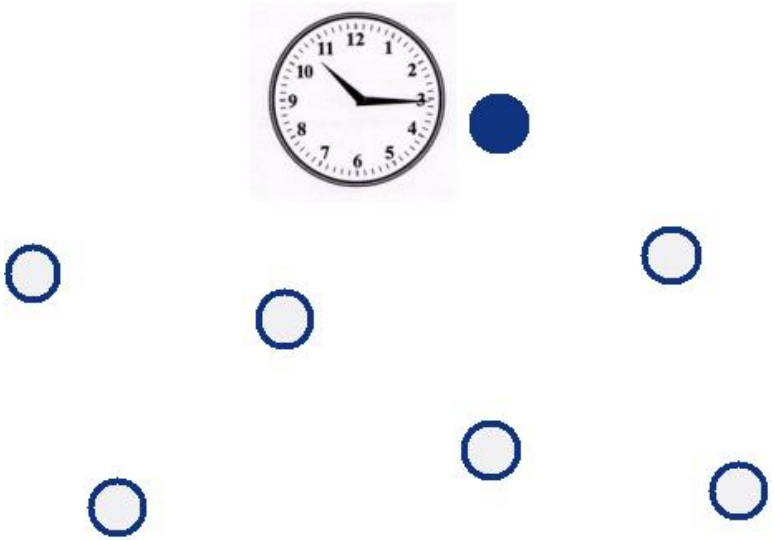

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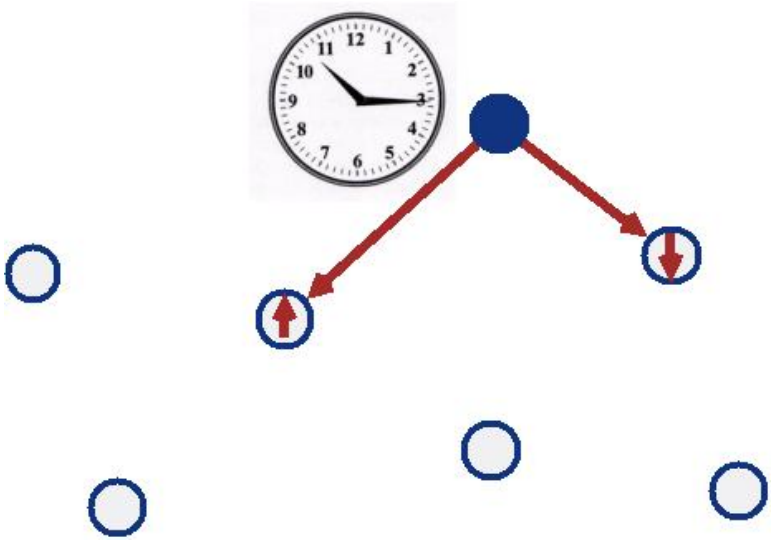

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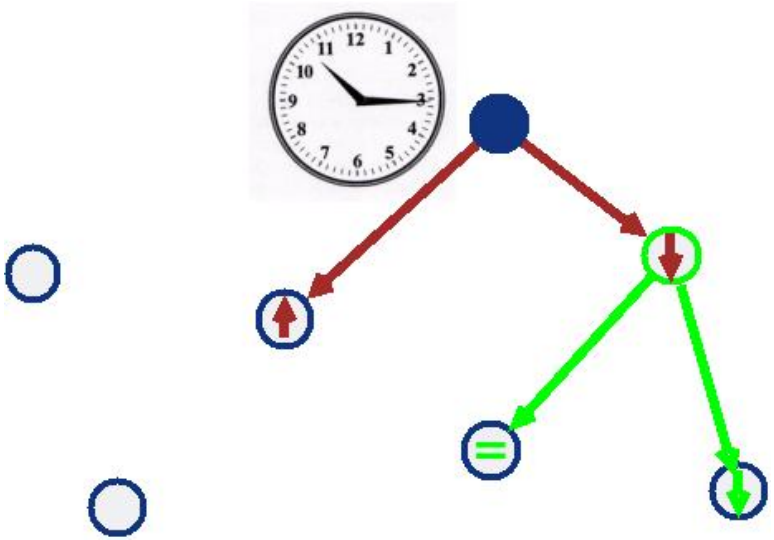

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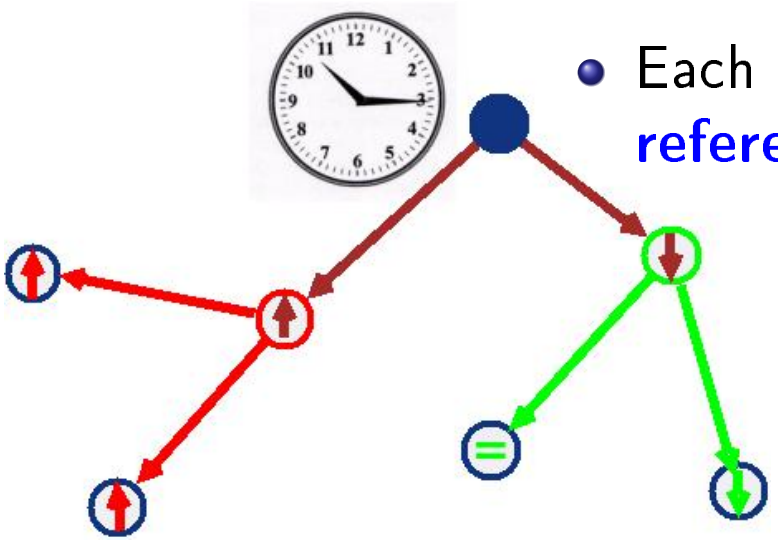

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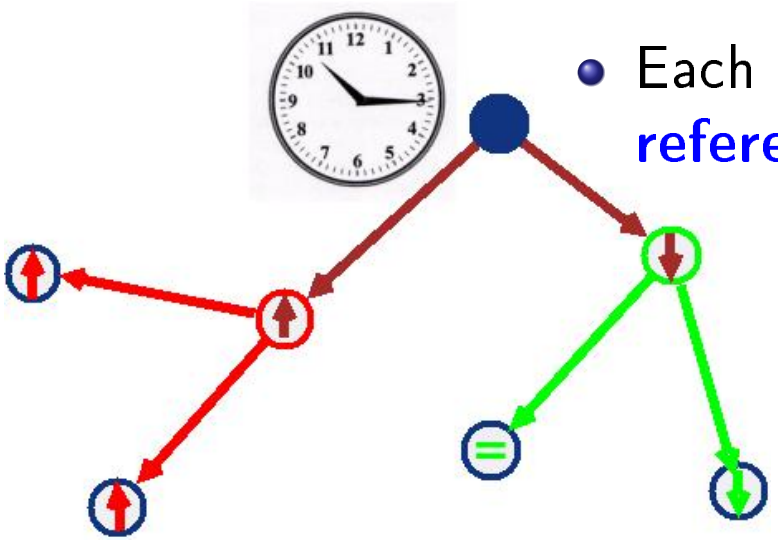

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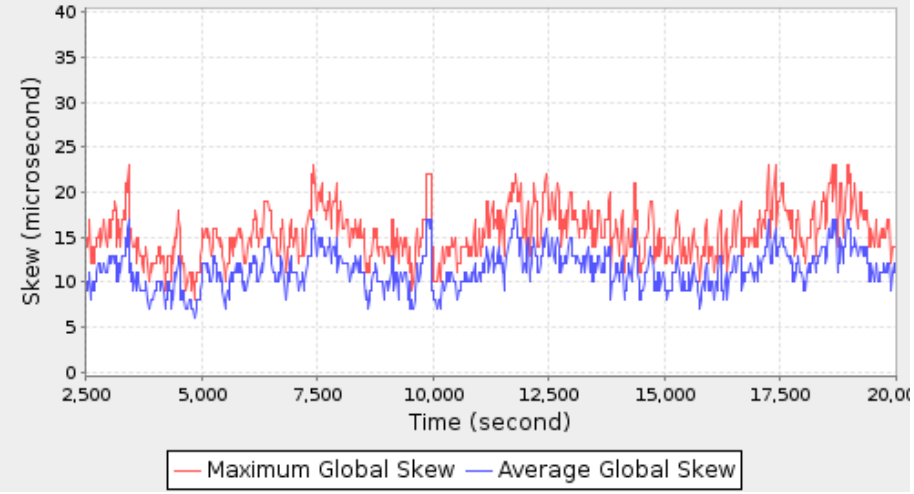


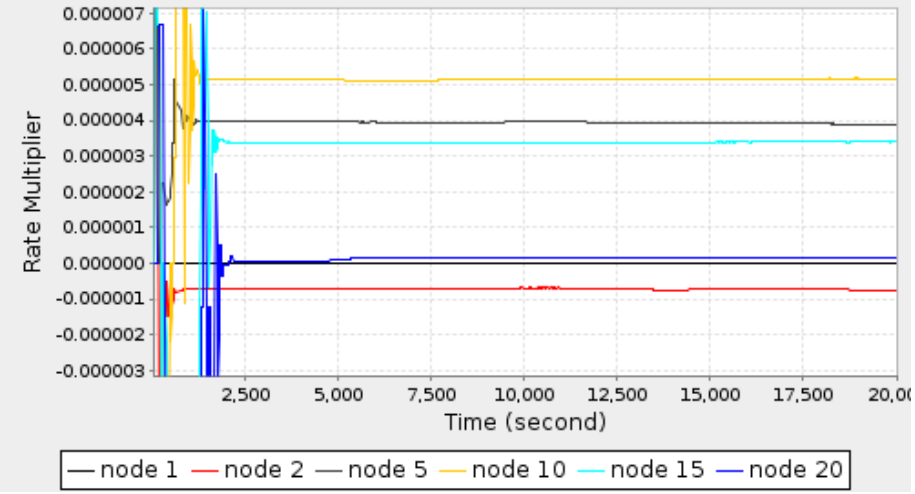

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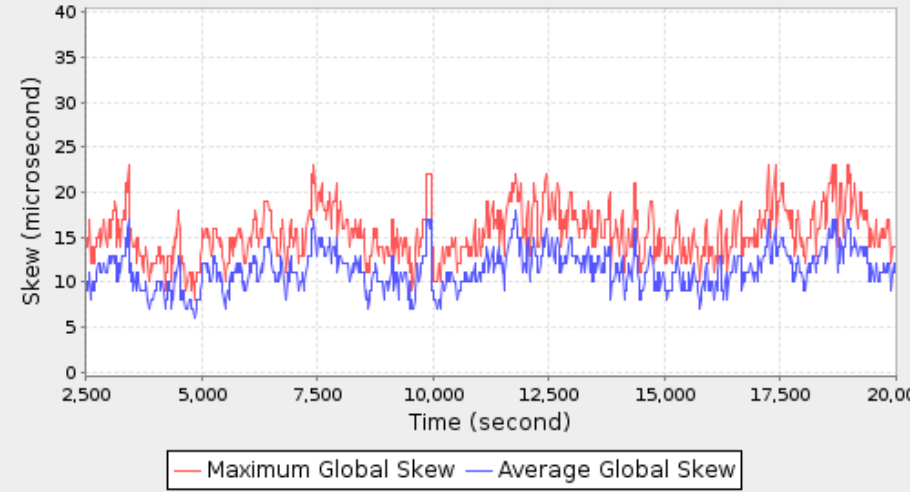


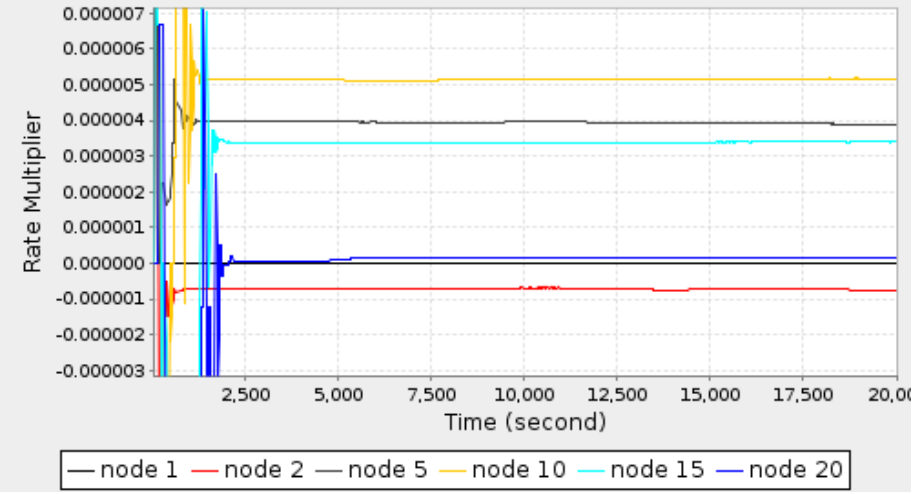


## Memory and Energy Requirements

| | FTSP | PulseSync | FCSA | AVTS |
|---|---|---|---|---|
| **CPU** | $\approx$ 5440 $\mu s$ | $\approx$ 5440 $\mu s$ | 5620 $\mu s$ for $\lvert\mathcal{N}\rvert = 1$ | $\approx$ **175** $\mu s$ |
| **Message Length** | 9 *bytes* | 9 *bytes* | 15 *bytes* | 9 *bytes* |
| **RAM** | 40 *bytes* | 40 *bytes* | 64*$\lvert\mathcal{N}\rvert$ *bytes* | 9 *bytes* |
| **ROM** | 18000 *bytes* | 17856 *bytes* | 20660 *bytes* | **15696** *bytes* |

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# References


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