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MESA: A Formal Approach to Compute Consensus in WSNs

Federico G. Zacchigna*, Ariel Lutenberg* and Fabian L. Vargas**

*Laboratorio de Sistemas Embebidos (FIUBA) **SiSC Group (PUCRS)

Introduction and objectives

Consensus algorithms are implemented over Wireless Sensor Networks (WSN) for computing a distributed variable measurement or performing Data Fusion (DF). The MESA approach is a novel consensus algorithm that implements the transmission censoring technique aiming to reduce the energy used for reaching consensus. Moreover, it makes use of neighborhood data, which allows it to perform estimations over unknown distributed variables. This condition renders the proposed approach more efficient than the existing censoring techniques found in the literature.

The consensus process starts with the measurement of a set of initial values named initial vector or initial state. We will consider each of the measurements a Gaussian distributed Random Variable (RV) with Probability Density Function (PDF) as in (1) or (2), for a detection or a estimation scheme respectively.

$$X_i \overset{\mathcal{H}_h}{\sim} \mathcal{N}\left(\mu_h, \sigma^2\right)\right), \text{ with } h \in \{0, \ldots, h_{max}\} \quad (1)$$

$$X_i \sim \mathcal{N}\left(\mu, \sigma^2\right)\right), \text{ with } \mu \in \mathbb{R} \quad (2)$$

Different schemes are shown in the following table:

Table 1: Cases classification according the censoring technique. *knw*, *unkwn*, *ngbhd* and *N/A*, are used for *known*, *unknown*, *neighborhood* and *Not Applicable* respectively.

Case	WNS type	Consensus strategy	Distribution type	Data usage	Estimation Detection
I	Cluster	standard	kwn/unkwn	N/A	Both
II		censoring	kwn	local	Detection
III		censoring	kwn/unkwn	ngbhd	Both
IV	Distributed	standard	kwn/unkwn	N/A	Both
V		censoring	kwn	local	Detection
VI		censoring	kwn/unkwn	ngbhd	Both

Cases I and IV are the standard consensus algorithms for clustered and distributed WSN respectively. Case II is the one studied in Rago's work. The article related to this poster is focused on cases I to III. Case III is the one that provides a new way of facing the consensus problem by using neighborhood data.

MESA algorithm

The algorithm may be resumed in the following way:

- Node in the first TS sends its data.
- The k node sends it if the $k-1$ has not send its data.
- The k node sends it if the $k-1$ has send its data and the DR in k is fulfilled.
- The k node does not sends its data if $k-1$ sent it and the DR in k is not fulfilled.

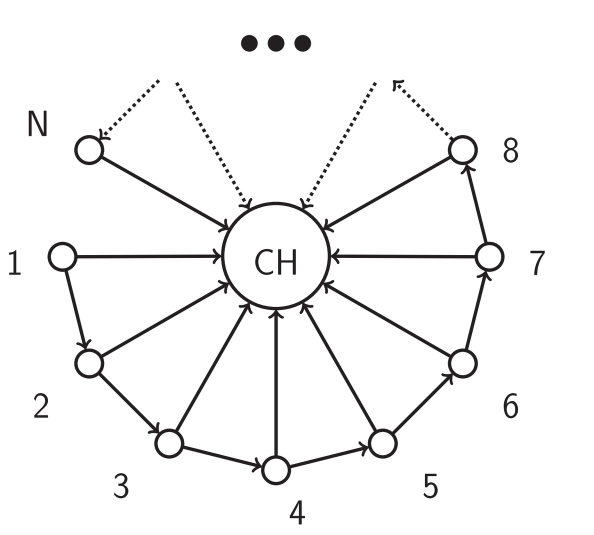

Figure 1: This figures shows the CH and the N nodes around it and how they communicate.

by saying 'k node', it means the 'the corresponding node in the k TS'.

A good way of representing the algorithm is shown in Figure 2, where the horizontal axis represents the TSs.

In each TS the corresponding node has a probability $\mathbf{P}(\mathrm{TX}_k)$ of performing the transmission and a probability $\mathbf{P}(\mathrm{NO\text{-}TX}_k)$ of censoring it, except in the first where the transmission is mandatory.

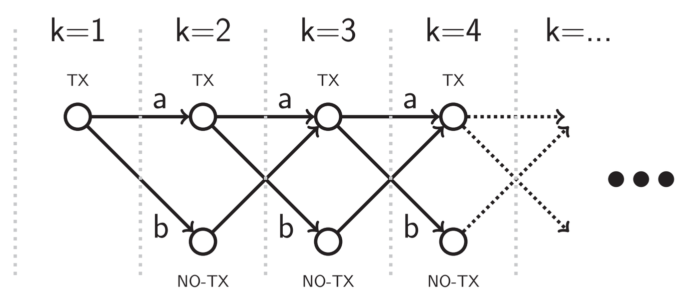

Figure 2: Graph representing the algorithm.

An error arises due to the performed estimation:

$$error_{III_i} = \begin{cases} 0 & \mathrm{TX}_i \\ X_i - X_{i-1} & \mathrm{NOTX}_i \end{cases} \quad (3)$$

and its distribution can be seen in Figure 3.

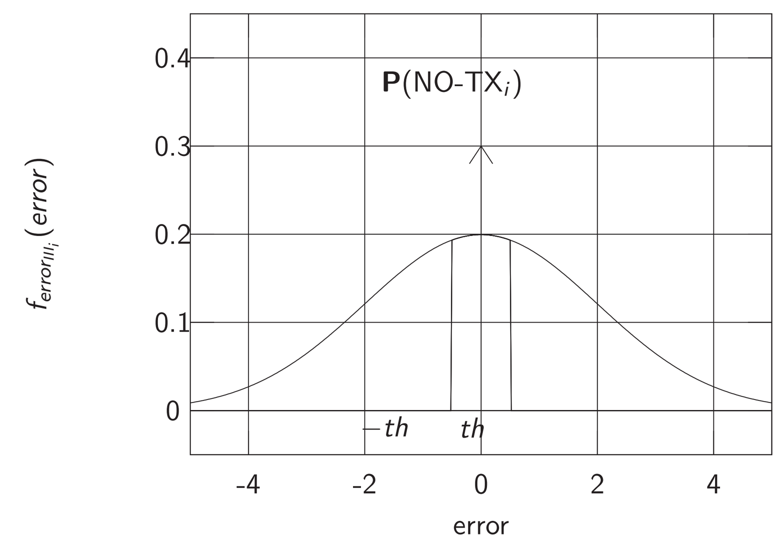

Figure 3: The error PDF for the case III.

By doing this, we may calculate the $\hat{X}_{CH_{III}}$ value in the CH as:

$$\hat{X}_{CH_{III}} = \left(\frac{1}{N}\sum_{i-1}^{N} X_i\right) + \left(\frac{1}{N}\sum_{i-1}^{N} error_{III_i}\right) = X_{CH_I} + error_{III} \quad (4)$$

where X_{CH_I} is the one from case I, the 'ideal case'. With these approach we may say, that in the CH we compute the mean of every X_i plus an error, which hast known statistics. We are able of computing the final variance obtained in the CH ($\hat{X}_{CH_{III}}$).

Simulation and results

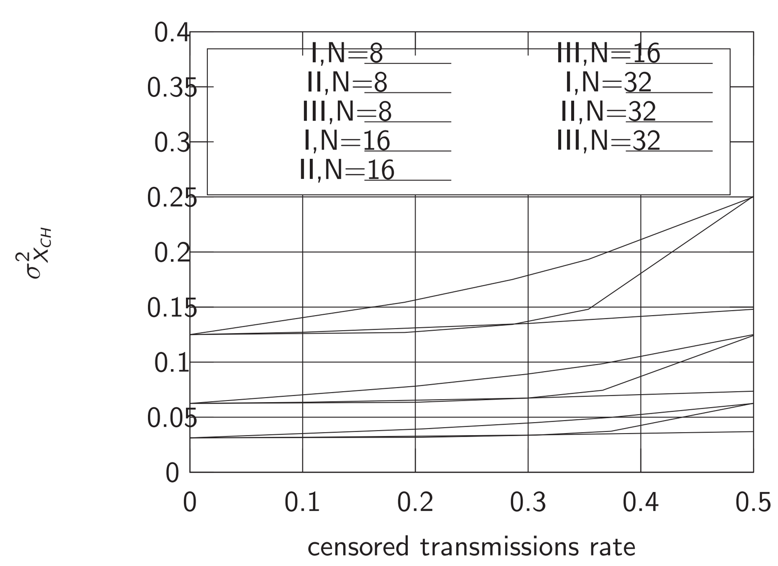

Figure 4: The X_{CH} variance as a function of the CTR.

Case I works as benchmark in Figure 4. The following results may be extracted:

- For CTR $\in \{0, 0.5\}$ the algorithm becomes dummy, the DR result is always the same.
- For a CTR between 0.10 to 0.35, the algorithm achives the best results.
- For CTR above 0.35, case III derates and case II outperforms it.

Conclusion and future work

In this work an introduction to a new approach of consensus algorithms has been presented, which is based on the censoring technique (silent agreement) applied to distributed consensus algorithms and adds the use of neighbors data, in this way much more information is available at the moment the DR is evaluated. Based on the encouraging results, future research arise and it will mainly aim to find an optimal DR and estimation for different WSN topologies.

As a general conclusion, this work is the first approach to this new idea and based on the results showed in here, it can be seen the big potential, that the MESA algorithm has for the energy consumption of WSNs that make use of consensus.

References:

[1] Rago, Constantino; Willett, P.; Bar-Shalom, Y., "Censoring sensors: a low-communication-rate scheme for distributed detection," Aerospace and Electronic Systems, IEEE Transactions on, vol.32, no.2, pp.554,568, April 1996

[2] Zacchigna, Federico G.; Lutenberg, Ariel, "A novel consensus algorithm proposal: Measurement estimation by silent agreement (MESA)," Embedded Systems (SASE/CASE), 2014 Fifth Argentine Symposium and Conference on , vol., no., pp.7,12, 13-15 Aug. 2014

Contact:

Laboratorio de Sistemas Embebidos
Facultad de Ingeniería - UBA
Paseo Colón 850, CABA
E-mail: federico.zacchigna@gmail.com