Self-accounting in architecture-based self-adaptation: online appendix

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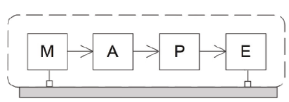
1 Self-accounting properties computation

For the computation of T and Av we consider the structure of the patterns composed of sequential components (like in the single MAPE loop) and/or parallel components (as in the various patterns where the $*$ association is involved). In this first formulation of the properties computation, for the sake of simplicity, we include interactions with both the knowledge and the other components in the characterization of a single component. A more fine-grained definition is matter of future work.

To evaluate the self-accounting property, we start by considering a managing system composed of a single MAPE loop as the one illustrated in Fig. 1(a).

Let us assume that each component in a MAPE loop is augmented with annotation concerning T_i and Av_i, with $i \in \{M, A, P, E\}$, respectively. In this case we can evaluate the latency time T_{single} and the availability Av_{single} associated with the execution of a single loop with the formulas given in Fig. 1(b).



(a)

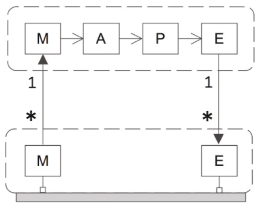
$$T_{single} = \sum_{i \in \{M,A,P,E\}} T_i \tag{1}$$

$$Av_{single} = \prod_{i \in \{M,A,P,E\}} Av_i \tag{2}$$

(b)

Fig. 1. Single MAPE loop

To complete the analysis of the managing system self-accounting property, we now provide the computation of T and Av for the different composite patterns presented in literature. We start with the aggregate pattern illustrated in Fig. 2 (a). Depending on the meaning of the $*$ association, we can have different measures associated with the pattern. Fig. 2 (b) illustrates $T_{aggregate}$ and $Av_{aggregate}$, for the pattern, when the number of involved M, E groups working in parallel is k, and considering the different meaning of the $*$ association.



(a)

$*$ means ALL:

$$T_{aggregate} = \max_{j=1...k} T_{M_j} + T_{single} + \max_{j=1...k} T_{E_j} \tag{3}$$

$$Av_{aggregate} = \prod_{j=1...k} Av_{M_j} * Av_{single} * \prod_{j=1...k} Av_{E_j} \tag{4}$$

$*$ means AT LEAST ONE:

$$T_{aggregate} = \min_{j=1...k} T_{M_j} + T_{single} + \min_{j=1...k} T_{E_j} \tag{5}$$

$$Av_{aggregate} = 1 - (\prod_{j=1...k} (1 - Av_{M_j})) * Av_{single} * 1 - (\prod_{j=1...k} (1 - Av_{E_j})) \tag{6}$$

$*$ means SOME, i.e., a subset of m groups, with $m < k$:

$$T_{aggregate} = \max_{(j=1...m)} (T_{M_j}) + T_{single} + \max_{(j=1...m)} (T_{E_j}) \tag{7}$$

$$Av_{aggregate} = \prod_{(j=1...m)} Av_{M_j} * Av_{single} * \prod_{(j=1...m)} Av_{E_j} \tag{8}$$

(b)

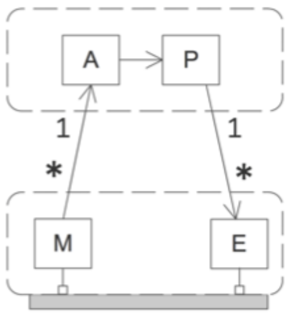
Fig. 2. Aggregate MAPE loop

Let us consider now the master-slave pattern illustrated in Fig. 3(a). As before, we can have different T and Av associated with the pattern depending on the meaning of the $*$ association. If the number of involved M, E groups working in parallel is k, the values of $T_{master-slave}$ and $Av_{master-slave}$, for the pattern considering the different meaning of the $*$ association are illustrated in Fig. 3 (b).

Let us consider now the regional pattern illustrated in Fig 4(a). Considering a single P, if the number of involved M, A, E groups working in parallel is k, the values of $T_{regional}$ and $Av_{regional}$, for the pattern considering the different meaning of the $*$ association are shown in Fig. 4 (b).

Let us consider now the hierarchical pattern illustrated in Fig. 5 (a) with 2 levels of hierarchy (levels can be any number from 1 to hl). We can have different T and Av associated with the pattern depending on the number of hierarchy levels and on the meaning of the $*$ association. Let us denote the number of levels with l ($l = 1 \dots hl$), the number of MAPE loop working in parallel at level l is denoted as k_l. We show the computation of $T_{hierarchical}$ and $Av_{hierarchical}$, for the pattern considering different meaning of the $*$ association in Fig. 5 (b).

Finally, considering the information-sharing pattern illustrated in Fig 6(a), if the number of involved M, A, E groups working in parallel is k, the values of $T_{information-sharing}$ and $Av_{information-sharing}$, considering the different meaning of the $*$ association, is presented in Fig. 6 (b).



(a)

$*$ means ALL:

$$T_{master-slave} = \max_{(j=1...k)} T_{M_j} + T_A + T_P + \max_{(j=1...k)} T_{E_j} \quad (9)$$

$$Av_{master-slave} = \prod_{(j=1...k)} Av_{M_j} * A_A * Av_P * \prod_{(j=1...k)} Av_{E_j} \quad (10)$$

$*$ means AT LEAST ONE:

$$T_{master-slave} = \min_{(j=1...k)} T_{M_j} + T_A + T_P + \min_{(j=1...k)} T_{E_j} \quad (11)$$

$$Av_{master-slave} = 1 - (\prod_{(j=1...k)} (1 - Av_{M_j})) * Av_A * Av_P * 1 - (\prod_{(j=1...k)} (1 - Av_{E_j})) \quad (12)$$

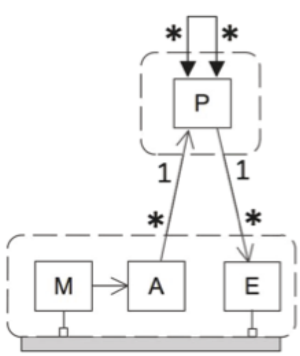
$*$ means SOME, i.e., a subset of m groups, with $m < k$:

$$T_{master-slave} = \max_{(j=1...m)} (T_{M_j}) + T_A + T_P + \max_{(j=1...m)} (T_{E_j}) \quad (13)$$

$$Av_{master-slave} = \prod_{(j=1...m)} Av_{M_j} * Av_A * Av_P * \prod_{(j=1...m)} Av_{E_j} \quad (14)$$

(b)

Fig. 3. Master-slave MAPE loop



(a)

$*$ means ALL:

$$T_{regional} = \max_{(j=1...k)} (T_{M_j} + T_{A_j}) + T_P + \max_{(j=1...k)} T_{E_j} \quad (15)$$

$$Av_{regional} = \prod_{(j=1...k)} (Av_{M_j} * Av_{A_j}) * Av_P * \prod_{(j=1...k)} Av_{E_j} \quad (16)$$

$*$ means AT LEAST ONE:

$$T_{regional} = \min_{(j=1...k)} (T_{M_j} + T_{A_j}) + T_P + \min_{(j=1...k)} T_{E_j} \quad (17)$$

$$Av_{regional} = 1 - (\prod_{(j=1...k)} (1 - Av_{M_j})(1 - Av_{A_j})) * Av_P * 1 - (\prod_{(j=1...k)} (1 - Av_{E_j})) \quad (18)$$

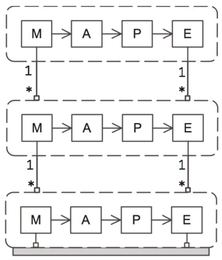
$*$ means SOME, i.e., a subset of m groups, with $m < k$:

$$T_{regional} = \max_{(j=1...m)} (T_{M_j} + T_{A_j}) + T_P + \max_{(j=1...m)} (T_{E_j}) \quad (19)$$

$$Av_{regional} = \prod_{(j=1...m)} (Av_{M_j} * Av_{A_j}) * A_P * \prod_{(j=1...m)} Av_{E_j} \quad (20)$$

(b)

Fig. 4. Regional MAPE loop



(a)

$*$ means ALL:

$$T_{hierarchical} = 2 * (\sum_{l=1...hl} \max_{j=1...k_l} T_{single_j} + T_{single}) \tag{21}$$

$$Av_{hierarchical} = 2 * (\prod_{l=1...hl} \prod_{j=1...k_l} Av_{single_j} * Av_{single}) \tag{22}$$

$*$ means AT LEAST ONE:

$$T_{hierarchical} = 2 * (\sum_{l=1...hl} \min_{j=1...k_l} T_{single_j} + T_{single}) \tag{23}$$

$$Av_{hierarchical} = 2 * (\prod_{l=1...hl} (1 - (\prod_{j=1...k_l} (1 - Av_{single_j})) * Av_{single}) \tag{24}$$

$*$ means means SOME, i.e., a subset of m_l groups, $m_l < k_l$, for each level l:

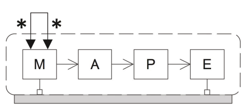
$$T_{hierarchical} = 2 * (\sum_{(l=1...hl)} \max_{(j=1...m_l)} T_{single_j} + T_{single}) \tag{25}$$

$$+ \sum_{(i=1...hl)} \max_{(j=1...m_i)} T_{single_j} \tag{26}$$

$$Av_{hierarchical} = 2 * (\prod_{(l=1...hl)} \prod_{j=1...m_l)} Av_{single_j} * Av_{single}) * \prod_{(i=1...hl)} \prod_{j=1...m_i)} A_{single_j} \tag{27}$$

(b)

Fig. 5. Hierarchical MAPE loop



(a)

$*$ means ALL:

$$T_{information-sharing} = \max_{j=1...k} T_{M_j} + \sum_{i \in \{A,P,E\}} T_i \tag{28}$$

$$Av_{information-sharing} = \prod_{j=1...k} Av_{M_j} * \prod_{i \in \{A,P,E\}} Av_i \tag{29}$$

$*$ means AT LEAST ONE:

$$T_{information-sharing} = \min_{j=1...k} T_{M_j} + \sum_{i \in \{A,P,E\}} T_i \tag{30}$$

$$Av_{information-sharing} = 1 - (\prod_{j=1...k} (1 - Av_{M_j})) * \prod_{i \in \{A,P,E\}} Av_i \tag{31}$$

$*$ means SOME, i.e., a subset of m groups, with $m < k$:

$$T_{information-sharing} = \max_{(j=1...m)} (T_{M_j}) + \sum_{i \in A,P,E} T_i \tag{32}$$

$$Av_{information-sharing} = \prod_{(j=1...m)} (Av_{M_j}) * \prod_{i \in A,P,E} Av_i \tag{33}$$

(b)

Fig. 6. Information-sharing MAPE loop