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OPTIMIZATION OF NETWORK TOPOLOGY IN A CIMM SYSTEM USED IN ORGANIZATION MANAGEMENT

Summary: CIMMs (Computer Integrated Manufacturing systems) are important systems for the overall automation of manufacturing enterprises, especially big ones. The general issues of the computer system topology were analyzed earlier. The present case study concerns the detailed design of the optimum LAN for the managerial sphere, based on the actual data for a big Polish household appliance manufacturer. For the data, the optimal LAN topology is determined, assuming the development of democratic networks. On the example of a big household appliance manufacturer, we define the first thread through the CIMM system, i.e.

from the System Media tracing the costs of working media per a single appliance, via the cost accountancy up to a management subsystem. We describe the architecture of the System Media and the software architecture. We present the general scheme of the production data input and the general diagram of the cost accountancy subsystem. For the first management function of the CIMM system, we propose the accountancy information processing based on the total manufacturing costs related to individual appliances. Further development of the System Media System is discussed in short.

Keywords: Automation, manufacturing, organization management.

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1. Introduction

When designing a CIMM system, a designer should think about the communication network topology, determining it during some actual and not virtual considerations. To understand the designing process and to teach it successfully, it seems worthwhile to start from an actual case study and proceed to more complex cases. This approach has been assumed for this paper. The initial data are taken from the example of Polar, the former biggest household manufacturer (enterprise) in Poland.

In a similar situation, high technology providers usually adopt the top-down approach trying to develop new standards and interfaces between two or more spheres and to design and implement the novel systems basing on these standard and interface definition. The results are, in general, spectacular system failures or very expensive solutions.

The article presents the notion of CIMMs [Franasik et al. 2001], some basic information about the general topologies of CIMMs [Izworski, Lewoc 2003a: Izworski, Lewoc, Skowroński 2003b: Izworski, Lewoc 2003c; Lewoc, Izworski, Skowroński 2006a, Lewoc, Izworski, Skowroński et al. 2009], determined on the basis of robustness evaluation (μ-function), a proposal of the optimal network topology assuming democratic character of the network, proven for the initial network data. Some hypotheses for more general networks are also given.

2. Some introduction to CIMMs

2.1. Initial information

The notion of CIMMs (Computer Integrated Manufacturing and Management System) was introduced for the first time in [Franasik et al. 2001; Lewoc, Izworski, Skowroński (2006a]. Such systems are severely needed in actual enterprises, especially in big factories involved in manufacturing. In spite of high demand for CIMMs, ICT people cannot present any good offer; the ICT technology providers specialized in management cannot and do not wish to be involved in the manufacturing problems and those specialized in manufacturing cannot and do not wish to cope with management issues.

Intensively advertised work on standards for development of standards for management and manufacturing systems seems to base on a rather naïve assumption that good standards on some novel solutions may be obtained without educating people of detailed knowledge in all areas covered by the overall system.

Considering it, a team of ICT and automation designers commenced initial design and research work oriented towards the development of a reasonable process for design and development of CIMMs. This work included some approach to the optimization of the communication network topology [Izworski, Lewoc, Skowroński 2003b: Izworski, Lewoc 2003c; Lewoc, Izworski, Skowroński et al 2009], and performance evaluation/prediction of actual computer networks [Izworski, Lewoc (2003a; Izworski, Skowroński, Lewoc 2004; Lewoc, Izworski, Skowroński2006b; Lewoc, Izworski, Skowroński2007; Lewoc, Izworski, Skowronski et al. 2010a; Lewoc, Izworski, Skowronski 2010b; Lewoc, Izworski, Skowronski et.al 2010 c].

2.2. General approach to CIMMs design

The general approach to CIMMs design is described e.g. in [Izworski, Lewoc, Skowroński 2007]. The general structure of any CIMM system could be planned only in a very general way at present. Therefore, it is not reasonable to design a solution for all possible CIMM problems at the very beginning of the design work. The basic **working media** (variables) proposed for the Media System include: **electric power** (active and reactive power, voltage, current), **gas** (flow, calorific value), **fuel** (weight), **water** (flow, temperature), **steam** (flow, temperature, pressure), **compressed air** (flow, temperature), **waste water** (oxygen demand, heavy metals, suspended solids, oil content, pH, flow), **waste gases** (flow, CO content, SO_x content, NO_xcontent) [Lewoc, Chomiak-Orsa, Izworski et al. 2013].

The general structure of the System Media is presented in Figure 1. This structure is commonly used in the power industry.

Thus, the first thread in the CIMM system, i.e. the minimum set of tasks needed for the development of an interconnection of the CIMMGs and CIMMTs useful and profitable for the enterprise involved, should be defined, feasible to be designed, worked out and implemented by a finite team. Basing on this experience and worked out standards, it should be possible to design and implement further CIMM threads. The first thread in the CIMMs is called the System Media and its architecture is presented in Figure 1.

The most attractive functionality of the managerial part of CIMMS in the first thread seems to be the Accountancy Department calculating the working media costs per a single product or a small production lot as presented in Figure 2. There is no revolution needed to organize it; the only what is needed is to develop settling pro-

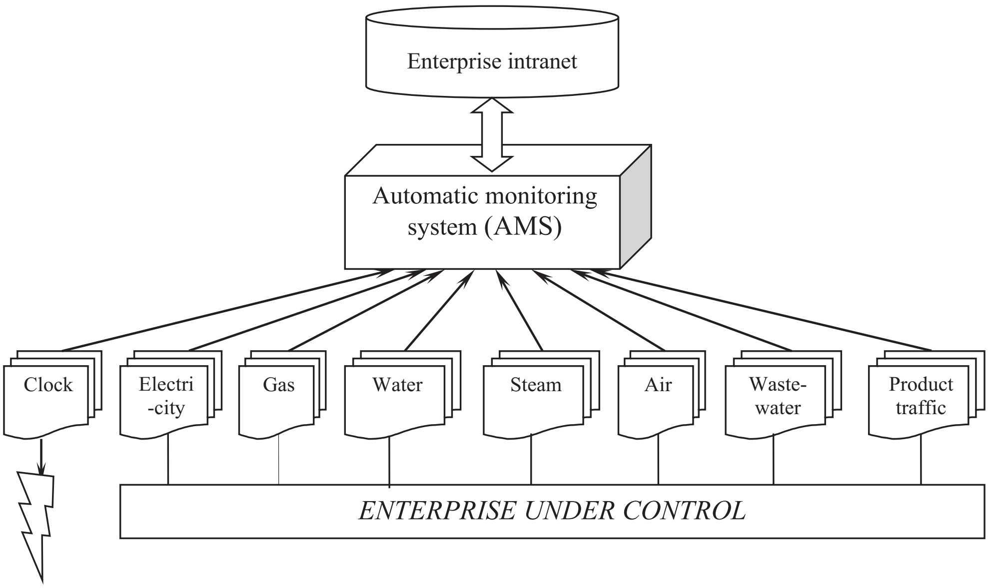

Figure. 1. General structure of System Media

Source: own elaboration.

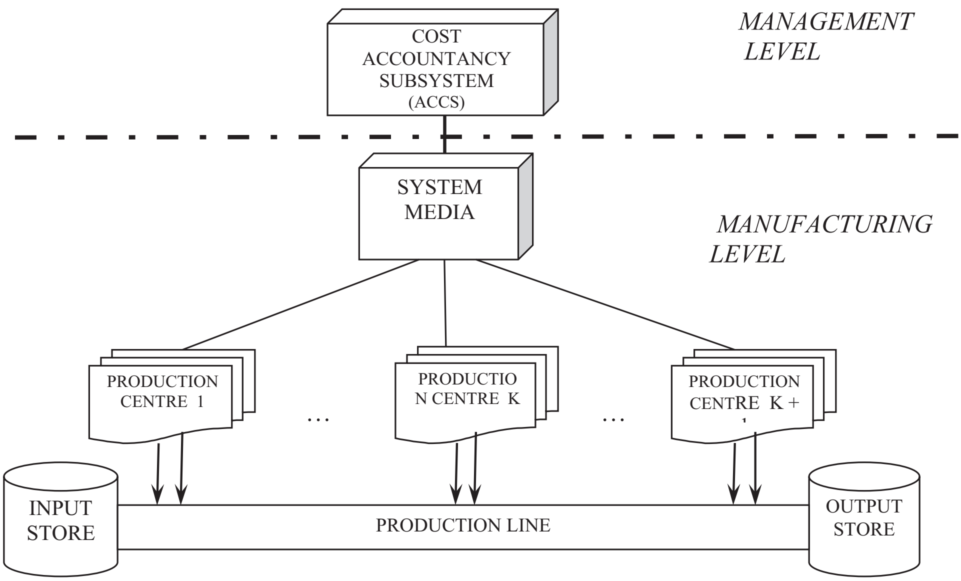

Figure 2. The first thread through CIMMs

Source: own elaboration.

grams for working medium consumption for the System Media presented in Figure 1 and to charge individual users with the working media costs in e.g. minutely and not monthly cycles.

The manufacturing level of the enterprise generally consists of the input store providing raw materials for production/manufacture of household appliances, the production line and the output store for storage and shipment of ready products. It was decided that the first thread should be based on the working media monitoring system (System Media). The rationale is as follows:

– The costs of working media constitute a major component of the total product/appliance production costs equal from some 20% in typical manufacturing plants to more than 60% in metallurgical plants and mines.
– The problems of media cost monitoring are similar for any manufacturing enterprise and the standards as well as interfaces developed for one enterprise may be easily used in other enterprises.
– Technical solutions of media monitoring have been successfully developed for the professional power generation and distribution systems also in the country case study [Lewoc et al. 2013] and may be applied in the System Media.
– The departments responsible for delivery and monitoring of the working media serve and know all units of their enterprises what may be of high importance for successful implementation of the relevant CIMM systems.

The present paper is devoted to devising some optimum topology for the communication network for the management part of CIMMs.

3. Optimal topology of the management of CIMMs communication network

3.1. Enterprise description

The managerial component of the enterprise (the component) needed some three hundred people to prepare the production and management processes and to sell the products (various types of freezers, refrigerators, washing machines, dish washers, etc.). The component was organized into several levels of hierarchy where any entity had to be provided with a possibility of direct contacting with their superior (transmission of reports, reception of commands) entities, subordinate ones (transmission of commands, reception of reports) and with the cooperating entities on the same hierarchy levels.

For such a general organization, we will try to propose an optimum LAN communication network.

3.2. Basic requirements for the communication network

The team, basing on the biggest experience available in the country [Han, Lewoc, Izworski et al. 2008; Lewoc et al. 2008; Lewoc, Izworski, Skowroński et al. 2011a; Lewoc, Izworski, Skowroński 2011b], formulated and adopted a good design practice as follows:

To achieve implementation and operation success of any large scale LAN communication network, its topology should be (in an ideal case) an isomorphic image of the network interconnecting human beings and technical equipment.

This rule is used, often, for the software topology; the team think that it should be used to the hardware topology since such isomorphism is very much beneficial for the rather complex processes of communication network design implementation and operation.

The enterprise presented with in the paper is Polar, Wrocław (the enterprise), the former biggest household appliance manufacturer in the country. The general organization of the management component of the enterprise is shown in Figure 3.

The other common-sense requirement is that the network should be democratic. This implies that the ICT equipment is identical for each user and that the optimization should be based on the maximization of the quality of service for the worst served user.

Another non-trivial requirement for the network is that it should be optimized from the point of view of robustness. That is true: in the present time of HiTech, earlier reliability based criteria are not enough; in present days a designer has to do their best to ensure adequate resistance to disturbance, i.e. the robustness. Some work has been done concerning a comparison of the basic two network topologies: the com-

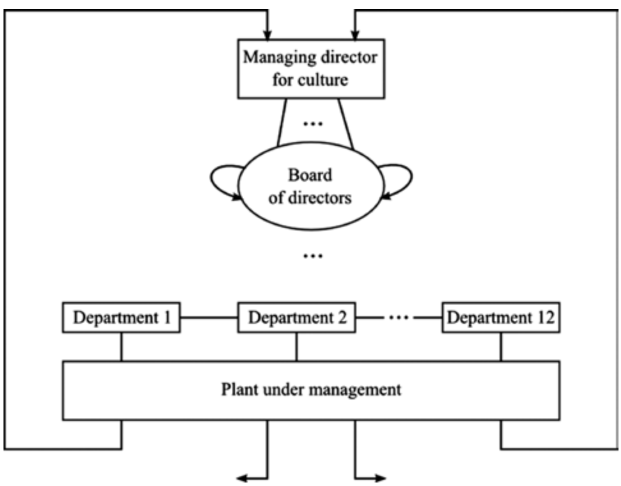

Figure 3. General organization of the managerial component of the enterprise

Source: own elaboration.

mon medium topology and the star one. To facilitate understanding of the present article, some citation of the works is presented below.

3.3. General topology of the network

The general topology of the Network can be, therefore, depicted as in Figure 4.

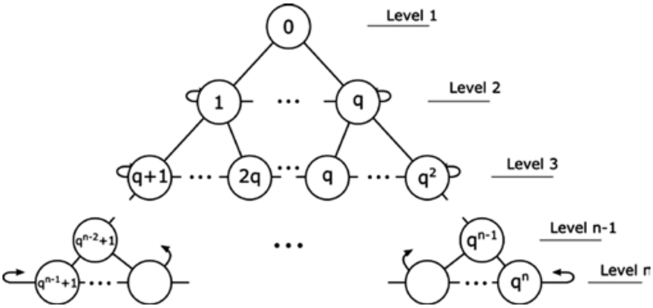

Figure 4. General topology of the network

Source: own elaboration

It may be noticed that the proposed numbers of the network nodes (switches) along the extreme RH branch meet the assumptions of the geometric series of the integer quotient *q* and the first term a1 and the numbers of nodes from the level 1 to *n* are equal to the partial sum of the geometric series, i.e.:

$$S_n = \frac{1-q^n}{1-q} \tag{1}$$

Individual branches in this network represent network links (hops) and, on the basis of the earlier discussion, are the same, so – without any worsening of the generality, are assumed to be equal 1. For the optimization, we have to determine *q* minimizing the optimality criterion defined hereinafter.

3.4. The optimization criterion

The objective of any democratic network should be that any user (k-th, $k = 1,\dots,q^n$) of the network obtains the same service quality as any other user within the same class (on the same level in this case). Considering the fact that the network is homogeneous in normal operating conditions, this means that the objective function should be the biggest distance from the k-th to any other user (node) in the network in normal operation (i.e. via horizontal links).

Note that we have to consider only the standard connections (closed loops) in the network; any emergency connections are used in abnormal (emergency) network

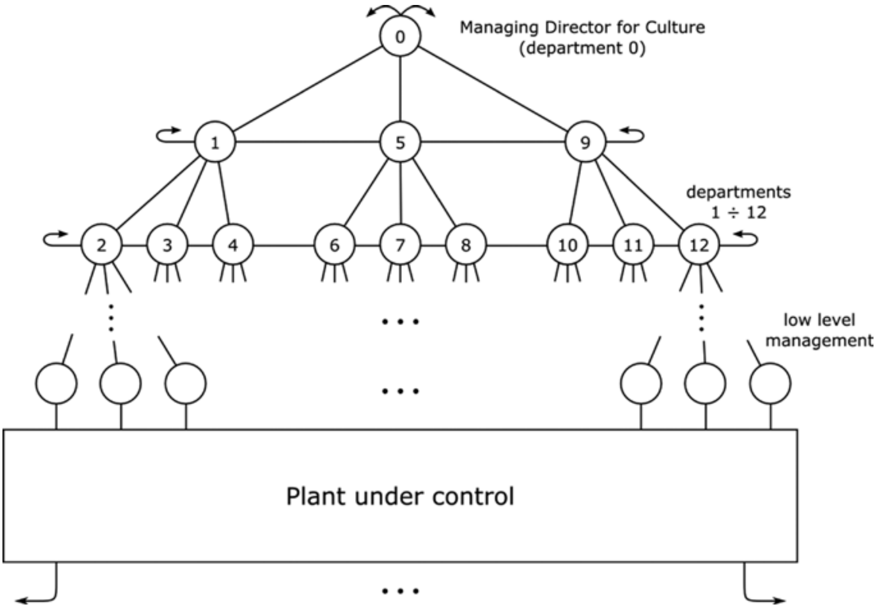

Figure 5. Optimal network for the case study

Source: own elaboration.

conditions; in this case the designer has to consider quite other criteria, e.g. the minimum time to restore the normal conditions.

Note also that the topology should be extended to the complete form shown in Figure 4; incomplete network (missed nodes on the n-th level imply, obviously, non democratic distribution of work of the users on the (n-1) level).

3.5. Optimal topology for the case study network

Determination of the optimum network for the case study is equivalent of finding the quotient q for which, for the minimum level number $n(q)$ such that the number of nodes of the network, i.e. the partial sum of the geometric series:

$$S_{n(q)} = \frac{1-q^{n(q)}}{1-q} \geq 300\,, \tag{2}$$

the maximum number of links (hops) between the nodes $q^{n(q)-1}+1$ and q^n, $d(q)$, is the lowest value what is equivalent to that $q^{n(q)-1}(q-1)$ is of the lowest value. For the case study, it can be simply verified directly.

Let us note that we may limit our investigations to $2 < q < 300$. Indeed, for $q = 1$, we have the case of a common media network, disqualified by the robustness investigation results.

On the other hand, for $q > 300$, we have $n(q) = 1$, so the number of links (hops) $d(q)$, mentioned above equals q and, obviously:

$$\prod_{q>300} d(q+1) > d(q)\ . \tag{3}$$

For $2 < q < 300$, the values of $n(q)$ and $d(q)$ were verified by direct calculations; $d(q)$ assumes the minimum value for $q = 3$.

Thus, considering the democratic criterion and the number of network nodes/switches needed, the optimal communication network for the case study is the one shown in Figure 5.

4. Conclusions

Assuming the democratic criterion defined in the paper, the three-party communication network is the optimal one for the case study of 300 network nodes/switches, i.e. network users.

A hypothesis has been defined that the same holds true for any network of limited size (finite *n*), observing the democratic criterion in the understanding of the present paper.

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OPTYMALIZACJA TOPOLOGII SIECI W SYSTEMACH CIMM WYKORZYSTYWANA W ZARZĄDZANIU ORGANIZACJAMI

Streszczenie: CIMMs (zintegrowane systemy wytwarzania) są szczególnie istotne dla wdrażania całkowitej automatyzacji dużych przedsiębiorstw produkcyjnych. Autorzy skupili się na analizie optymalizacji topologii sieci, które wpływają na doskonalenie zintegrowanych systemów informatycznych w obszarze automatyzacji procesów produkcyjnych. W analizowanym przez autorów rozwiązaniu optymalizacja układów dotyczy przede wszystkim optymalizacji modułu rozliczania mediów wykorzystywanych w procesach produkcyjnych, co powinno w bezpośredni sposób przełożyć się na doskonalenie procesów decyzyjnych w organizacji. Monitorowanie oraz kontrolowanie procesów zużycia mediów nadal stanowi duży problem optymalizacyjny w wielu zakładach produkcyjnych, toteż problemy optymalizacji topologii sieci stanowią nadal ważną kwestię w obszarze doskonalenia zarządzania organizacją.

Słowa kluczowe: automatyzacja, produkcja, zarządzanie organizacjami.