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CLOUD COMPUTING FOR MANUFACTURING EXECUTION SYSTEMS AND PROCESS CONTROL

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Abstract

Paper deals with actual problem orientated to cloud technology applying within implementation of information systems in area of manufacturing corporations and process control. The mainly part is aimed at analysis of requirements to MES systems, which are directly responsible for support of production control and global monitoring of manufacturing process. Special part is aimed at creating of recommendations for implementations of SaaS (Software and services) within MES system implementation. Practical realisation was orientated to simple model realisation with using integration gate for connection manufacturing systems which do not support communications via cloud protocols (http, SOAP).

Keywords: control system, information system, MES, ERP, SCADA, Cloud, SaaS, SOAP, REST

1 INTRODUCTION TO CLOUD COMPUTING

Cloud Computing is a modern term applied to large, hosted datacenters that offer various computational services on a “utility” basis. The general understanding of Cloud Computing is related to an on-demand service model by which various different resources (hardware, software, and services) are delivered over the network, which could be the Intranet of a company or the Internet when the service is ordered from an external provider. The network connection is always based on Internet-protocols, such as the TCP/IP protocol stack that is used to communicate between the cloud provider and the cloud consumer.

The resources involved in cloud computing primarily are computational resources (e.g. server, storage, network, software), and they are primarily provided as services for the user according to the following rules (3).

1. Cloud represents a pool of computing resources and services which are shared among subscribers.
2. The charges for resources and services using an “as used” metered and/or capacity based model.
3. Resources and services are delivered virtually, although they are represented by physical hardware.
4. The provisioning and configuration of resources and services is performed on the “self service” in an automated way with no human operator assistance.

Currently, there are three possible cloud service layers that can be used in combination to build a full end-to-end cloud (2):

- Software as a Service (SaaS) — offers an application, such as ERP, on demand over the network or internet.
- Platform as a Service (PaaS) — providers offers a complete development platform including the necessary built-in services, such databases, applications and midleware on demand over the network.
- Infrastructure as a Service (IaaS) — a service offering hardware and software infrastructure components, such as computers and storage systems.

A cloud (Back end) may be hosted by an enterprise or service provider and provide services to the clients (Front end), represented by PCs, Tablets, Smart phones, as shown in Figure 1.

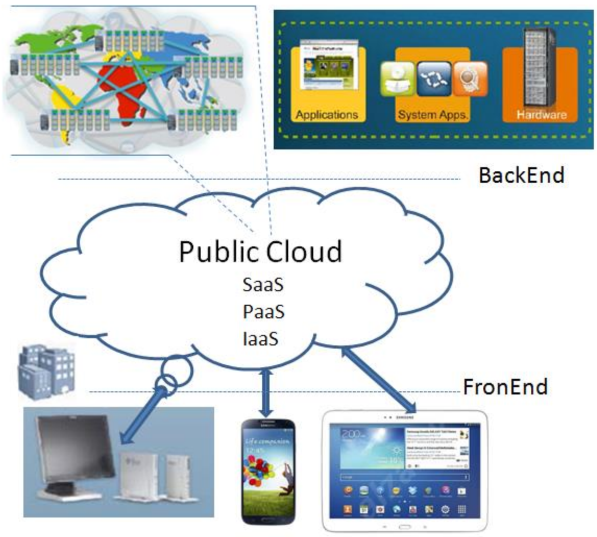

Figure 1: Public Cloud

2 CLOUDS AND INFORMATION SYSTEMS OF PRODUCTION

Information systems of nowadays production companies are based on ERP systems (Enterprise Resource Planning), which are responsible for corporate resources and processes, but as well as on Manufacturing execution systems (MES) that are generally used to manage and monitor work-in-process on ShopFloor. MES are typically integrated with various machine control systems (PLCs) or visualization of production process (SCADA), as shown in Figure 2.

ERP systems integrate, automate, and create processes that capture how the business works. It is important to ensure the data quality and allocate adequate computing resources and bandwidth to provide timely results for ERP users. ERP works in so called a transaction mode with less critical response times. Therefore ERP could be implemented in Cloud by the Software as a Service model (SaaS). ERP package can run in Cloud and be available for WEB clients over TCP/IP connection. The software and client standardization might solve the business issues of small and mid-sized companies. However, it lacks the customization flexibility that might be required by larger enterprises.

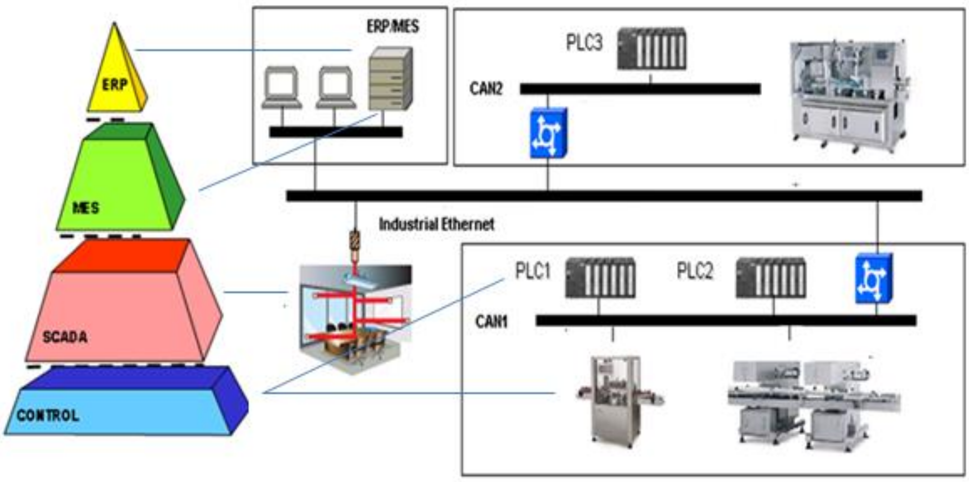

Figure 2: Information system of a Production company

The example of ERP implementation via Cloud is shown in Figure 3. Production company has to maintain end-user hardware (Desktop infrastructure) and local network LAN/WLAN to enable access to Cloud via WAN connection to Internet for PCs, Thin clients, Tablets and Mobile clients. The hardware of ERP system is not needed in location and is not visible to the users, because ERP is just provided as a software service as WEB based application.

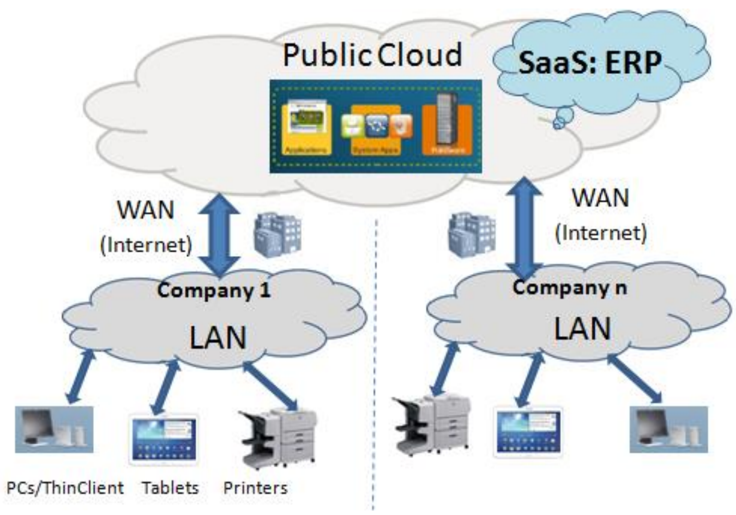

Figure 3: Example of ERP implementation via Public Cloud

3 MES INTEGRATION WITHIN CLOUD

Manufacturing Execution Systems (MES) systems are critical element for a successful manufacturing and production processes, because they integrate machine control systems with enterprise information systems. MES keep track of all manufacturing information, for instance the production orders, recipes, product and process monitoring and overall product traceability. The integration of manufacturing execution system, as the middle layer of manufacturing planning and control system, with the other levels provides real-time information and helps to make critical decisions in real-time

Manufacturing Execution Systems (MES) are typical by the need for long lifecycles. As soon as IT solution is in production, the companies want to ensure production stability and avoid unnecessary changes in software applications or basic IT infrastructure. The risk and cost of service interruptions become much higher due to their deep integration within production process. Therefore, an availability and performance of mission-critical manufacturing application is vital for company. The main goal is to support the execution in real time and an improvement of overall productivity. In addition, MES system has to meet the following requirements:

- High system availability (~99%, 24h/7d)
- Fail-safe setup (redundancy, fast recovery)
- Prolonged lifecycle (~10 years)
- Restricted maintenance windows (e.g. holidays),
- Limited changes (restricted patching, releases)
- Support of various machine control systems

Therefore, it is a really important to ensure that MES system runs as expected and that there are adequate computing resources and bandwidth to provide timely results. Moreover, end user devices in manufacturing application cannot be reduced just to WEB based clients (1). Manufacturing execution system software that includes supervisory control and data acquisition features has to collect data from machine sensors, scanners and save it in production databases for next processing. Then, the software-based algorithms send real-time instructions to devices such as programmable logic controllers (PLC). As explained, MES end devices are much more complex and have to use the different protocols and software packages, than the simple WEB based clients of ERP systems, see Figure 4.

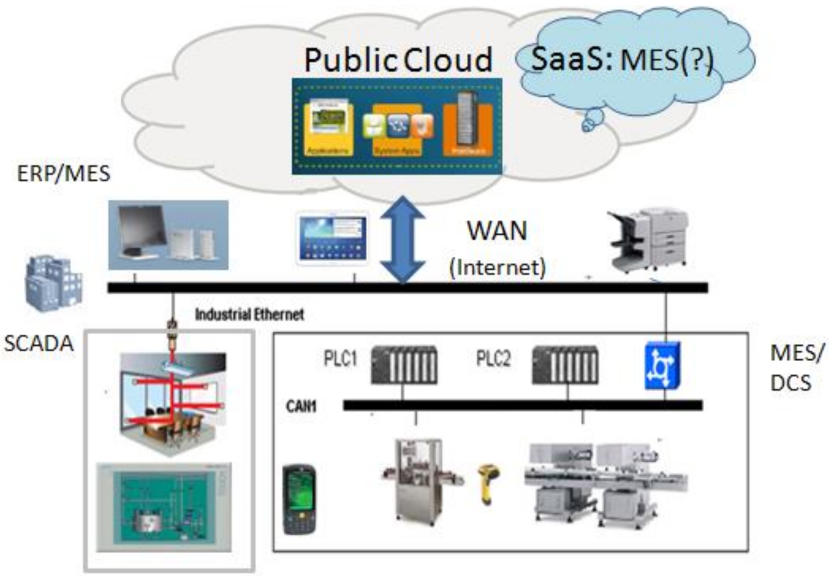

Figure 4: Example of MES implementation via Public Cloud

4 MODEL OF MES IMPLEMENTATION VIA CLOUD

According to the previous chapter, the integration of MES to Cloud requires significant adjustments. In theory, MES/HMI/SCADA could be moved to the cloud with limited impact on operations, provided the infrastructure offers adequate reliability, uptime and response time. There are several recommendations which could be taken into consideration for implementation of MES in PUBLIC cloud:

- Cloud SaaS service has to be established in accordance with the defined SLA (Service Level Agreement), consisting the requested response time T_{SLA} [ms], bandwidth P_{SLA} [Mbps], and number of concurrent users N(n).
- If the requested SLA cannot be granted by provider of Public cloud, the Private, or Hybrid cloud has to be used.
- Reliability of the connection to Cloud via Internet should be extended by using two independent WAN connections (different WAN providers) with respect to SLA.
- The end devices shall be divided to two groups (G_A, G_B), based on their possibilities to work directly with Cloud protocols (WEB client) or dependency on the specific communication protocol with a real-time requirements (for example OPC).
- Devices without direct WEB support (G_B) have to be connected to Cloud via Proxy gateway in order to translate non WEB traffic to the requested Cloud protocols, such as REST and SOAP.
- The critical MES data should be mirrored in Proxy cache to mitigate issues in case of Cloud service unavailability for limited time. The end user devices can work with information in Proxy cache (S_{Proxy}) until connection to Cloud is recovered.

Finally, it may be useful to create a simple model for integration of MES system with Cloud and SaaS. In accordance with above considerations, the proposed model is shown in Figure 5.

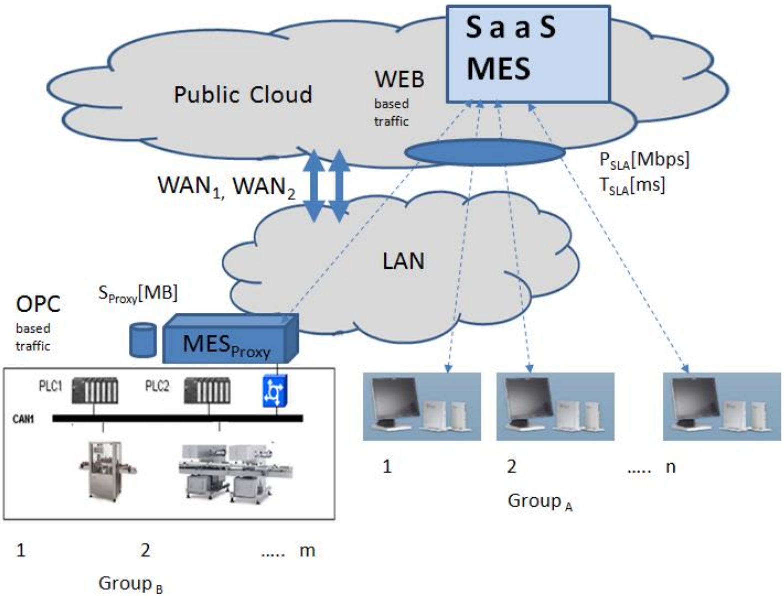

Figure 5: Simple model for MES integration with SaaS Cloud

In Figure 5, there are illustrated two group of devices ($Group_A$, $Group_B$) according to embedded support of Cloud protocols. The main focus is paid on keeping defined SLAs. There are two critical SLAs that are essential for MES integration. First, the response time cannot deviate from agreed value (T_{req}) more than defined difference (Δt), see Equation 1. Second, overall bandwidth of WAN connection (P_{WAN}) has to include required bandwidth of all $Group_A$ devices (n), plus a bandwidth of conversed protocol traffic for $Group_B$ (P_{Proxy}), as defined in Equation 2. Typically, the process control devices, such as PLCs and sensors, do not support Cloud protocols with Web based communication. Therefore the suggested dedicated gateway is applied to provide protocol conversion from OPC to REST, or OPC to SOAP. In addition, the gateway can act as Proxy, mirroring the critical interface data tables for end devices. The cache size (S_{Proxy}) has to be configured based on amount of devices and size of particular tables (S_i), as shown in Equation 3. As well as, the model includes for WAN connection two independent lines WAN_1, WAN_2.

$$T_{SLA} = T_{req} \pm \Delta t \quad (1)$$

$$P_{WAN} = \sum_{i=1}^{n} P_i + P_{Proxy} \quad (2)$$

$$S_{Proxy} = \sum_{i=1}^{m} S_i + \Delta S \quad (3)$$

5 CONCLUSION

Although cloud computing is virtually identical to the old mainframe model, it is still very hard to perform migration of MES systems to the Cloud, particularly in terms of building in satisfactory levels of security, resilience and responsiveness. Going straight to the cloud with no intermediary, on-premise solution just to mitigate infrastructure risks, reduce costs could cause more issues than benefits. Particularly, as the power of the cloud (scalability, virtualization) is not all that relevant to the fixed resource requirements and real-time requirements of an MES. With adequate bandwidth and an acceptable response time, integration of MES within cloud could be achievable. As well, there will be necessity to solve issue with integration of WEB incapable devices. The proposed model has shown the basic possibilities how to achieve integration and secure the requirements when moving to Public Cloud. Obviously, implementation of MES in Cloud will be challenging and require much more significant adjustments than simpler application of SaaS model for ERP.

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