Fusion of production, operation and maintenance data for underground mobile mining equipment

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Abstract

For integration purposes, a data collection and distribution system based on the concept of cloud computing could be possible to use for collection of data or information pertaining from various sources of data. From a maintenance point of view, the benefit of cloud computing is that information or data may be collected on the health, variability, performance or utilization of the asset. It is especially useful in data mining where different types of data of different quality must be integrated. This paper discusses the concept and presents one example from the underground mining industry.

Keywords: process control, cloud computing, CMMS, underground mining, load haul dump (LHD) machines

1. Introduction

Process control systems typically include one or more centralized or decentralized process controllers communicatively coupled to at least one host or operator workstation and to one or more process control and instrumentation device. Many industries also have software systems which execute applications related to business functions (ERP) or maintenance functions (CMMS). The integration of maintenance information, management and monitoring is essential in most industries, and a computer database of an organization's maintenance operations can be maintained in a CMMS software package. A computer database of information about an organization's maintenance operations is being maintained in the CMMS software package. The software has progressed from being a tool handling relatively simple maintenance planning to a window based, multi-user system that cover many maintenance functions. The CMMS system can handle a vast amount of data, opening up new opportunities for maintenance and simplifying the management of assets. A CMMS system also makes it possible for staff to become more productive, as paperwork can be minimized. In addition, a system can collect and store information in an easily retrievable format[1]. With CMMS, it is possible to detect problems before failure occurs; hence, there are fewer failures. Spare part planning, as well as preventive maintenance planning and more efficient use of staff recourses, are other advantages of CMMS.

Information in the CMMS system may be stored and used by maintenance personnel to monitor and maintain equipment. In any industry, the functions associated with process control activities, device and equipment maintenance and business activities such as process performance monitoring are separated, both in the location in which they take place and in the personnel who typically perform these activities. Furthermore, the people involved in these functions generally use different tools, such as different applications run on different computers. In many instances, these tools collect and/or use different types of data associated with or collected from the various devices within the process and are set up to collect the specific data they need. The maintenance personnel who are responsible for assuring that the equipment within the process is operating efficiently, repairing and replacing malfunctioning equipment, use tools such as maintenance interfaces which provide information about operating states of the devices within the process. Figure 1 shows a CMMS system and its typical connections.

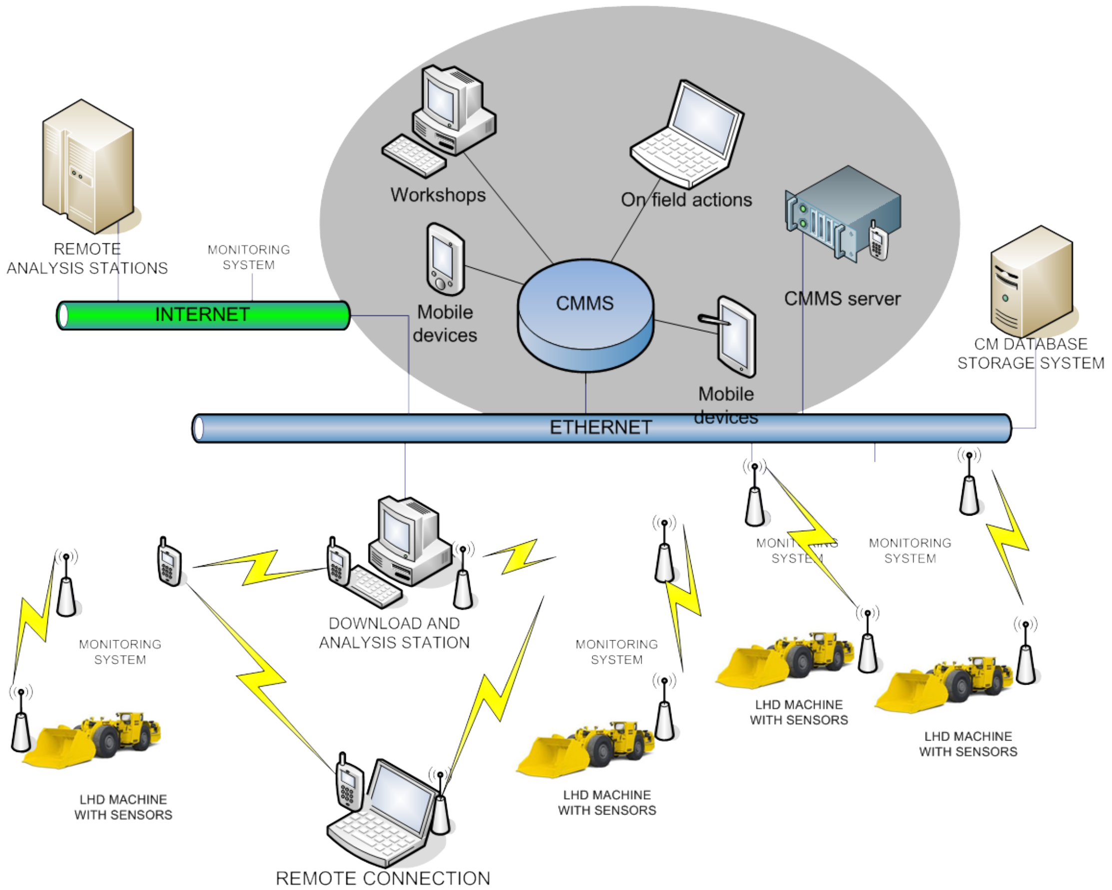

Figure 1. Typical architecture of maintenance information system[2]

2. Data fusion

A process control system includes data collection and a distribution system. It collects and stores data from different data sources, each of which may use it own proprietary manner of acquiring or generating the data. The data collection and distribution system makes the stored data available to other applications associated with or provided in the process control system or to applications associated with the data sources for use in any desired manner. Therefore, applications may use data from vastly different data sources to provide insight into the equipment's current operational status and to make better or more complete diagnostic or financial decisions. The information may then be sent to a process operator or maintenance person to inform him/her of current or future problems.

The detection of a machine problem, such as one which requires a shutdown, may cause business software to automatically order replacement parts or alert the business person that chosen strategic actions will not produce the desired results due to the state of the machine. There are, of course, many other applications to which the fusion data related to process control, equipment monitoring and performance monitoring data can be an aid by providing different and more complete information about the status of assets. Maintenance applications such as CMMS may be installed and executed by one or more of the user interfaces associated with the distributed process control system to perform maintenance and monitoring functions, including data collection.

3. Cloud computing

Cloud computing has been defined as "a model for enabling convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction" [(3)] . The cloud is a set of hardware, networks, storage, services, and interfaces that enable the delivery of computing as a service. The cloud provides the means through which everything from computing power to computing infrastructure, applications, business processes to personal collaboration can be delivered as a service[(3)(4)(5)] wherever and whenever it is required. Cloud services include the delivery of software, infrastructure, and storage over the Internet or Intranet (either as separate components or a complete platform) based on user demand. Unlike other approaches, the cloud is as much about the business model as it is about technology. Important drawbacks of the cloud are discussed in[(3)(6)(7)(8)] to be e.g bandwith-related and also issues related to having a third party involved (e.g security, compliance and regulatories). Various approaches to address challenges in order to get a trustworthy cloud computing environment are discussed in[(8)].

For asset management, the cloud seems to solve the problem of dispersed data stored in different repositories. The data collection and distribution applications may be dispersed throughout the network, and data collection may be accomplished at distributed locations. The collected data may then be converted to a common format at the distributed locations and sent to one or more central databases for subsequent distribution. These distributed databases constitute the asset cloud. The end users (maintenance personnel and operators) do not have to know anything about the underlying technology. A data collection and distribution system, the "asset cloud" was designed[2] to acquire data from various sources of data, format these data to a common data format or structure and then provide the data, as needed, to any of a number of applications run at a computer system or disbursed between workstations throughout the process control network. As it can fuse or integrate data from previously disparate and separate systems, it provides better measurement, viewing, control and understanding of the operation[9][10].

Generally speaking, some data collection routines should be created to collect data from disparate sources and to input these data in a common or consistent format into the cloud. The cloud operates as a data and information base to coordinate the distribution of data or information from one functional area, such as the maintenance area, to other functional areas, such as the process control or the business functional areas. As a result, the cloud may use the collected data to generate new information or data which can be distributed to one or more of the computer systems associated with the different functions; it may also execute or oversee the execution of other applications that use the collected data to generate new types of data.

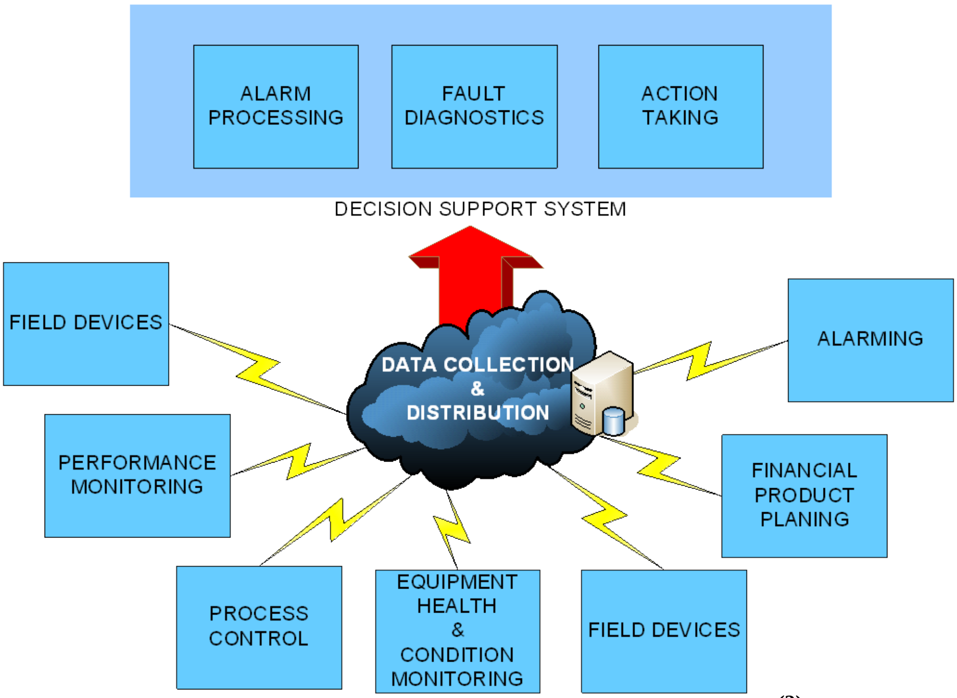

Figure 2. Services provided by the asset cloud[2]

Figure 2 is a simplified functional block diagram of the data flow and communication associated with or used by the asset cloud. The data collection and distribution system portrayed here receive data from numerous sources: a process control data source, an equipment or process health data source, a financial or production data source and a performance monitoring data source. The cloud collects the data from the data sources in a common format or converts those data, once received, into a common format for storage and later use by other elements, devices or applications in the process control system. Once received and converted, the data are stored in a database in some accessible manner and made available to applications or users within the asset cloud. Applications related to process control, fault diagnostics, predictive maintenance, financial planning, optimization, etc. may use, combine and integrate the data from one or more data source. This ensures better performance than in the past, when such data were not combined.

4. Knowledge Discovery in Databases (KDD)

Knowledge Discovery in Databases (KDD) has been called "the nontrivial extraction of implicit, previously unknown, and potentially useful information, from data"[(11)]. Data mining and knowledge discovery can be applied to historical data to optimally identify features relevant to the condition of equipment and associated thresholds and contexts. Based on this information, a model can be created for specific equipment to forecast its RUL (remaining useful life) and to determine the time interval to the next maintenance action. In this context, cloud computing is useful, as it can draw on data from a number of possibly remote sources and can handle large amounts of data. The data for this study has used the following steps from the concept of KDD[(12)].

1. Data cleaning: removal of noise and inconsistent data.

2. Data integration: combining of data from multiple sources. The production, maintenance and operational data are different in nature and originate from different sources but must be integrated to get a complete view of the operation and maintenance of the equipment (Figure 3).

3. Data selection: retrieval of data relevant for the analysis.

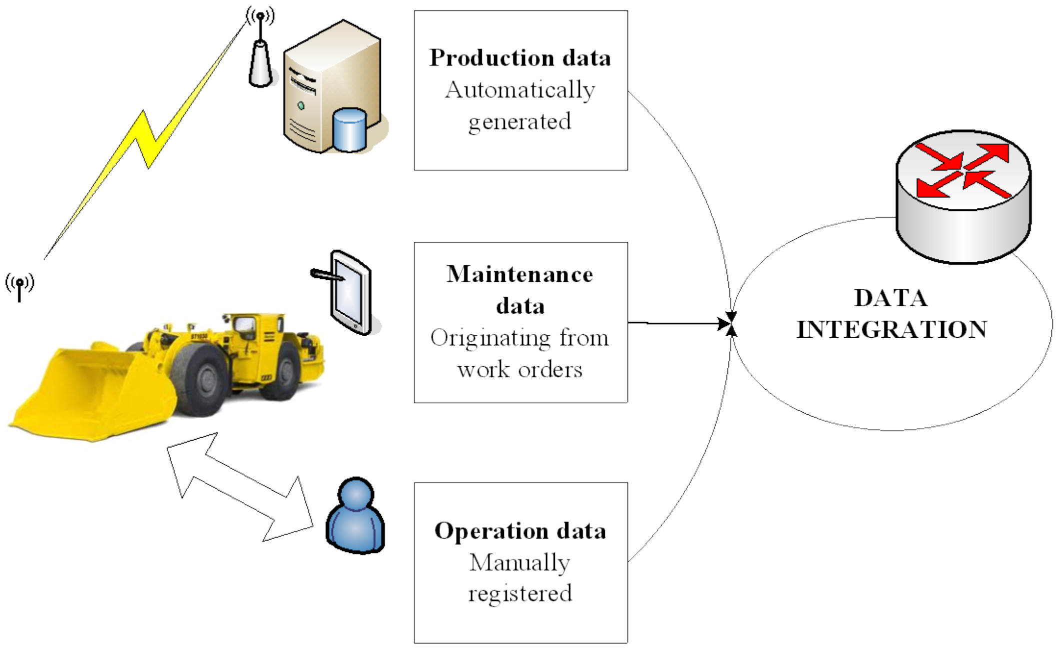

Figure 3. Data integration of data from different sources[(13)]

5. Case study

The case study is from a mine located in northern Sweden and is the second largest iron ore mine in the country. In the mining process, the ore is excavated and loaded by 13 Load Haul Dump (LHD) machines (Figure 4). The machines transport the ore and dump it into vertical shafts placed along the ore body. The LHDs have a capacity of 20 metric tonnes and are diesel powered.

5.1 Maintenance of underground mobile mining equipment

The maintenance of underground mobile mining equipment has several problem areas: harsh environment, potential risks and distant location of workshops. When a machine breaks down, there are two ways to handle the repair. Either the equipment has to be repaired on site at the production area or taken to the workshop. The difficulties involved in moving this type of large equipment are substantial but it might be difficult or unsafe to repair the LHD on site (depending on where and why it fails). For one thing, the harsh environment can cause problems. In addition, the workshops and facilities are located outside the production area; this is a major constraint in the transportation of large equipment to the workshop. The mine's maintenance philosophy is based on better maintenance performance. The plan is to frequently improve maintenance management systems, especially CMMS, to ensure better equipment availability and reliability.

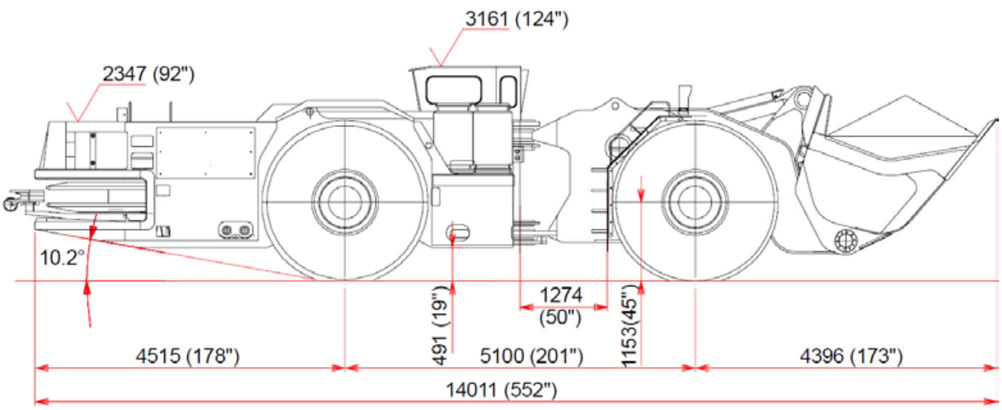

Figure 4. LHD machine (Courtesy of Sandvik)

5.2 Computerised Maintenance Management System in the underground mine

The maintenance department of the mine uses several planning and scheduling softwares to run the operation activities. One is called GIRON and is a mine planning and information system [(14)]. A second gives the maintenance cost data. The maintenance planner can sort the cost categories (highest to lowest) and go through them as per his/her requirement. The third software currently used in the mine is Movex; it is used for resource planning, scheduling and inventory control (material and spare parts). For the LHDs, the mine uses WOLIS, a decision and support system [(14)], that in real time guides the operator to make correct decisions. With this system, data can automatically be extracted from a machine in production by the server where it can be accessed via computer. Information such as bucket weight, time for unloading, equipment ID, location of loading and dumping etc. are registered in the system for every bucket load. Data are also collected manually; for example, the engine machine hours are collected manually once a week for each LHD.

5.3 Data collection and analysis

Production, operational and maintenance data covering the period January 2007 to August 2010 have been collected, analysed and integrated for two LHDs. The two machines were manufactured the same year and have the same specifications. The data analysed comes from different sources and have very different quality. The “known times,” when production stops and starts, come from automatically produced production data (Wolis) and are very accurate. The maintenance data are manually entered into the system. This human interference needs to be considered when analysing the data since it points to the possibility of errors in the calculations. When the workshop data and the automatically produced production data were compared, on many occasions when the machine was supposed to be in the workshop, it was really operating and vice versa. One third of the manually entered times are not consistent with the automatically recorded production times[10]. The time spent in workshop includes time to repair, as well as logistic times, such as waiting time in the repair queue or spare parts delays. In the mining industry, the actual repair times are rarely specified which is an important weakness of the data collection system. Furthermore, since enter and exit times to the workshop are manually entered into the system, their accuracy is not fully reliable. The available data for the LHDs can be described as follows:

- Maintenance data: The workshop records contain information on the time spent in the workshop, the estimated time for entering and leaving the workshop, the reason for maintenance and the measures taken. The workshop data are manually entered into the CMMS and are not as reliable as the automatically generated production data. From the maintenance data, it is possible to classify the failures and maintenance types that correspond to the different components and sub-systems of the LHD.

- Operational data: The data consist of idle-times (giving reasons for the idle-times and the idle-time in hours), operation time in hours for the automatic mode and daily tonnage produced. This information is manually entered into the system by the person responsible for LHD automation.

- Production data: These data are automatically and accurately generated production data on time for unloading each bucket, tonne/bucket, location of the loading and idle times.

As Figure 5 shows, if the workshop data are integrated with production data, one can accurately determine when the LHD was operating and when it was idle due to maintenance. The downtime registered between the loading on January 1 and January 2 shows a gap in production which, in this case, relates to the LHD being in the workshop.

MAINTENANCE DATA

DATE	TIME
20XX-03-14	12:50
20XX-03-14	12:52
20XX-03-14	12:54
20XX-03-14	12:56
20XX-03-14	12:58
20XX-03-15	12:27
20XX-03-15	12:29
20XX-03-15	12:31
20XX-03-15	12:33

Date	Failure report	Measures taken	Entering workshop	Leaving workshop	Idle time
20XX-03-14	Fan belt broken	Changing all belts and generator	6:00 PM		
20XX-03-15				10:00 AM	16.00

Figure 5. Example of integration of production and maintenance data[10].

6. Conclusions

Having an asset cloud providing data to end users facilitates the availability of collected data from different data sources. The collected data, i.e., process monitoring data and equipment monitoring data can be provided to different people, collected and used in a variety of formats and used by completely different applications for different purposes. The asset cloud is a feasible solution to the probem of bad data access. In addition, it can collect data and convert them if necessary into a common format or protocol that can be accessed and used by a number of interested parties.

The integration of different types of data may provide or enable greater equipment uptime, the avoidance of equipment failures and increased productivity.

A challenge in the continued development of the cloud concept stems from data fusion where different kinds of data with different quality and coming from different sources must be intelligently integrated. However, this paper gives an example from the mining industry where this integration has been done to obtain new useful information for the operation and maintenance manager. The cloud does not solve the issue of missing data or bad data entered into the system. The practical problems with questionable data can be the obstacle that prevents the cloud to be completely implemented in full scale.

Acknowledgements

The Swedish Foundation for Strategic Research (SSF), ProViking and Sandvik Mining and Construction are acknowledged for providing financial support during this research.

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