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Cloud-based Fleet Management System Proof of Concept

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OVERVIEW: In recent years, management strategies in the mining business have been shifting away from direct investment in expanding production, and focusing instead on efficiency by reducing operating costs and improving productivity. It was against this background that Hitachi undertook a proof of concept project using cloud technology for a mining industry FMS being developed, implemented, marketed, and maintained by Wenco International Mining Systems Ltd. This project involved implementing an FMS system platform on Hitachi's cloud (data centers) and testing its performance when offered as a cloud-based service via the Internet. Hitachi is using the project to assess its technical viability and identify where future improvements are required, with the intention of offering the service commercially in the future.

INTRODUCTION

THE mining business involves extracting minerals from mines and selling them. Factors such as the volatility of commodity prices and increasing extraction costs in recent years mean that one of the management challenges for mining companies is how to achieve stable earnings from this business. Past management strategies based around direct investment in expanding production are now giving way to a focus on efficiency with the aim of reducing operating costs and improving productivity. Mining companies are facing steadily rising operating costs, which are a consequence of factors such as compliance with environmental regulation and operating deeper mines. The aging of experienced staff and the rapid increase in personnel costs due to the difficulty of recruiting operators are also becoming increasingly pressing issues. With regard to productivity, the challenge when it comes to making improvements is how to make the best use of existing equipment in an environment in which new investment is constrained, given that equipment utilization in mining has traditionally been lower than that of other industries.

The mining industry fleet management system (FMS) supplied by Wenco International Mining Systems Ltd., a Canadian subsidiary of Hitachi Construction Machinery Co., Ltd., manages the status of dump trucks, excavators, and other mine site equipment. The dispatchers use the FMS to implement productivity by directing vehicle operators where to go. Whereas separate FMSs have traditionally been installed at each mine site, mine sites at isolated locations, for example, tend to face numerous system management challenges that include recruiting technical staff and ensuring a reliable supply of electric power. Because system outages reduce productivity, ensuring reliable FMS operation is an important issue for mining companies.

Hitachi, meanwhile, supplies operation and maintenance (O&M) cloud services that extend from on-site preventive maintenance applications to use in operation and management through the collection and analysis of operational and maintenance information from its social infrastructure businesses. These services help the operators of social infrastructure to achieve reliable and flexible operation and maintenance.

For the mining business, Hitachi believes that supplying the Wenco FMS as a cloud service will enable mining companies to overcome the operational challenges described above. Accordingly, it has conducted a proof of concept (PoC) project in conjunction with Wenco, with aims that include overcoming the technical issues associated with shifting the FMS to the cloud, and assessing its performance. This article describes the project and its results.

CONCEPT BEHIND CLOUD IMPLEMENTATION OF FMS

This section describes the structure and features of the current Wenco FMS, the concept behind implementing it in the cloud, and the associated challenges.

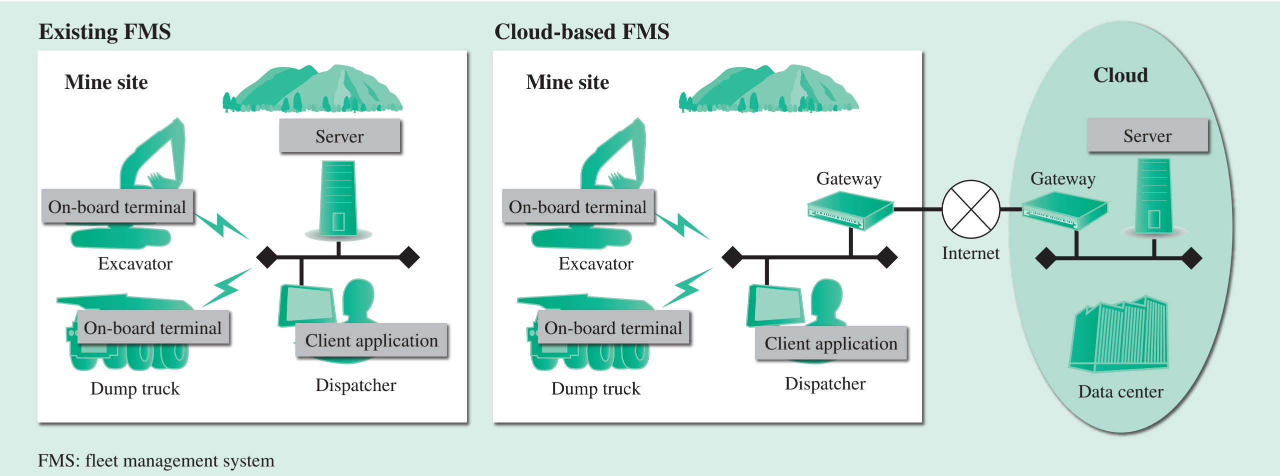

Fig. 1—Block Diagrams of Existing FMS and Cloud-based FMS.
The cloud-based FMS uses on-board terminals and client applications at the mine site that connect via a gateway and the Internet to a server located in the cloud.

Operating Environment of Current FMS

The FMS consists of a server that runs the FMS software, on-board terminals installed in each vehicle, and the client applications that the dispatchers use for their work. The on-board terminals connect to the server via a wireless local-area network (LAN). The dispatchers use their client applications to monitor vehicle status and issue commands to the vehicle operators. The server stores production data as it is collected from the extraction process, including production totals and details of vehicle operation. The server is commonly installed in a room at the mine site, where its operation is managed by on-site system technicians.

Advantages of Introducing Cloud-based FMS

Fig. 1 shows block diagrams of the existing and cloud-based FMSs. In the latter case, the server that was previously located at the mine site has been shifted to the cloud, with the on-board terminals and client applications connecting to it via a gateway and the Internet.

Hitachi sees the cloud-based configuration as having the following five advantages.

(1) Remote dispatching

Because the on-board terminals, server, and client applications connect via a gateway and the Internet, a cloud-based configuration means client applications can be located away from the mine site to allow dispatching to be performed from a remote command center (see Fig. 2). For example, since things like recruiting and stationing staff at mines in isolated locations often pose a problem, the cloud-based configuration makes it possible to set up the FMS based on remote dispatching by having a city-based command center.

(2) Ease of installation

Because there is no longer any need to set up a server at the mine site, the FMS can be installed quickly and at low cost. By reducing up-front costs, this should encourage the adoption of FMSs.

(3) Reliability and stability

Setting up the server on a robust cloud platform helps provide reliable server operation and reduces the risk of system faults.

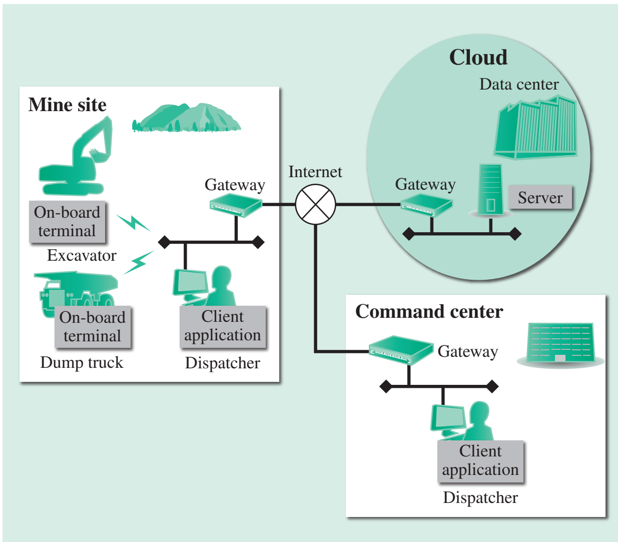

Fig. 2—Example System Configuration for Remote Dispatching Using Cloud-based FMS.
Remote dispatching allows operating instructions for vehicles at a distant mine site to be issued from a city command center.

(4) On-demand use

The ease of adding server capacity means that, in situations such as preliminary testing, the system can be used only when needed, and only to the extent needed.

(5) Access from mobile devices

Production data collected by the server can easily be accessed as required from mobile and other devices. This should help in ways that include faster management decision-making.

Challenges and Solutions of Cloud Implementation

Shifting the FMS to the cloud brings new challenges that do not arise with the current FMS, which is limited to the mine site. The following section lists three major challenges and how to overcome them.

(1) Stronger data security (confidentiality)

Because a cloud-based FMS needs to communicate via the Internet between the mine site and cloud, the system design requires adequate provision for data security.

Accordingly, it uses virtual private network (VPN) functions such as data encryption, tamper detection on communication circuits, and access authentication to deal with the potential interception of communication data.

(2) Change of communication control protocol

The current FMS is designed on the assumption that its communication is restricted to a LAN. Since most communications between the on-board terminals and the server are via wireless, communication control between these uses a non-session-based protocol that allows for the frequent packet loss that occurs in wireless communications. However, the use of Internet communications that accompanies the shift to the cloud requires that both the mine site and cloud change to a session-based protocol to allow the firewall to perform access control and to facilitate address conversion.

To achieve this, Hitachi added a new gateway function at the mine site to implement the change in communication control protocol (see Fig. 3).

(3) Reduction of communication delays

Implementing FMS in the cloud results in communication delays that are proportional to the physical distance between the mine site and the cloud. The round trip time (RTT) delay typically ranges between several tens and several hundreds of milliseconds. The addition of the new functions associated with the two challenges described above also introduces processing delays at both the mine site and the cloud. Furthermore, one of the features of the FMS is that it is a realtime system. The data on the on-board terminals, server, and client applications needs to be kept synchronized without delays. This is the most significant technical challenge to be overcome when implementing the system in the cloud.

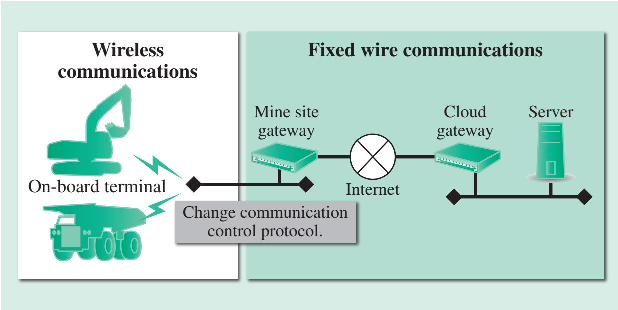

Fig. 3—Change of Communication Control Protocol for Cloud-based System.
The shift to a cloud-based system required a change from a non-session-based communication control protocol that assumed wireless communications with frequent packet loss to a session-based protocol that allows the firewall to perform access control and facilitates address conversion.

Accordingly, the project included testing of the benefits of installing wide-area network (WAN) acceleration, a notable technology of Hitachi's, to reduce communication delays. This WAN acceleration technology increases the speed of transmission control protocol (TCP) communications. In the past, it has commonly been installed to boost the speed of high-volume data transfers, such as for the sharing of files between multiple locations. In this case, however, it was used for the frequent but low-volume data transfers typical of machine-to-machine (M2M) communications.

In the PoC project, Teck Resources Limited of Canada handled testing of how users perceived system operation. With a view to future deployment, the project also encompassed the technical evaluation of long-distance communication between Canada and Japan.

PROOF OF CONCEPT WITH TECK

Overview

This testing assessed whether the system was viable for practical use at a mine site, looking from a customer's perspective at things like practicality and the changes in ease-of-use associated with the architectural change from an on-premises system to a cloud system.

TABLE 1. FMS Use Cases for Testing
A total of 10 test cases were identified to represent the main uses of the FMS in normal operation.

Client application	Example use case	Example operation
Fleet management application (4 use cases)	Dispatch truck to excavator	Issue notification to truck to go to different excavator for loading.
Location information application (4 use cases)	Edit mine map.	Edit map data indicating locations of extraction, storage areas, and routes.
Data management application (2 use cases)	Report generation	Output reports containing operating records or statistics.

The cloud server was set up at a data center in North America and the client applications and on-board terminals were installed at a Teck site in British Columbia in Canada. The evaluation was conducted by a team of five Teck staff who worked at the site, including dispatchers and their supervisors.

The testing covered 10 use cases for three client applications and encompassed core FMS tasks that are used on a routine basis (see Table 1). The evaluators operated the FMS in accordance with the procedures specified for each use case and scored the operation of the system using a four-point scale (perfect, good, not good, or bad) based on factors such as how it responded to these operations.

Test Results and Investigation

The scores were collated for each application and color-coded in accordance with the assessments (see Fig. 4). The following three conclusions were drawn from the dispatchers' assessments.

(1) The operation of the dispatching application was good, remaining unchanged from the non-cloud system.

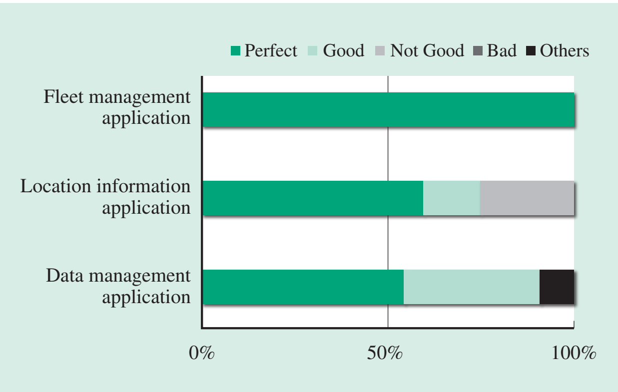

Fig. 4—Results of Dispatcher Assessments.
The assessments identified a problem with certain operations in the location information application taking too long.

(2) The location information application was deemed "not good" in 25% of responses. This highlighted a problem with particular operations taking too long as a consequence of using the cloud.

(3) In the case of the data management application, although the shift to the cloud made some operations slower, this was not by so much as to cause a problem in practice.

The deterioration in the ease-of-operation of the location information application was found to be caused by the longer time taken to synchronize data between the server and client applications after adjustments to map data. While it was initially assumed that this synchronization of adjustments to map data would not occur often, the users indicated that it would be a problem in practice because the function was in fact frequently used.

An analysis of network communications to further investigate the problem found that blocks of data were being sent at times when operation was impaired. A quantitative assessment and investigation based on these measurement results identified the following three measures that could minimize this problem in the future.

(1) Modify the client application design to allow users to continue working unimpeded while data is being synchronized.

(2) Shorten synchronization time by synchronizing data selectively to minimize the volume of data transfers between server and client application.

(3) Shorten synchronization time by making appropriate use of Hitachi's WAN acceleration technology to improve network speed and reliability.

PROOF OF TECHNOLOGY OF COMMUNICATION BETWEEN CANADA AND JAPAN

Overview

Some mining companies operate multiple mines that are separated by long distances in places such as North America or Australia, and there are cases when it is not possible to install the cloud server close to all mines. Particularly in the case of long-distance configurations involving intercontinental communications, the WAN RTT may be several hundred milliseconds or more, meaning that the FMS will likely experience major delays in its response time. Accordingly, Hitachi conducted operational testing of the FMS using long-distance communications between the mine site in Canada and the cloud server in Japan.

TABLE 2. System Configuration for PoC

The bandwidth bottleneck in the network was the 5-Mbit/s maximum capacity of the DSL. Its mean actual throughput was measured at 3 Mbit/s.

Item	Value
Cloud server location	Japan
Site location	Canada
Distance from server to site	8,000 km (approx.)
WAN	Internet
Access line to site	DSL
Mean throughput between server and site*	Downlink: 3 Mbit/s, Uplink: 3 Mbit/s
Mean RTT*	0.17 s

PoC: proof of concept WAN: wide-area network DSL: digital subscriber line
RTT: round trip time
* The mean server-to-site throughput and RTT measurements were made prior to implementing the enhancements described in the article.

In addition to the main FMS functions, the test system incorporated the three enhancements described above, namely the use of a VPN, new FMS functions, and WAN acceleration. The main objectives of the tests were to look for any problems with dispatch system operation and to conduct comparative testing to assess the delay improvement provided by the WAN acceleration technology.

Table 2 lists the system configuration. The bandwidth bottleneck in the system's network is the 5-Mbit/s maximum capacity of the digital subscriber line (DSL) to the mine site. The mean actual throughput was measured at 3 Mbit/s.

Testing

The following three steps were defined as representing a typical FMS operation.
(1) The operators use the on-board terminals on specific mine site vehicles to modify their operating status manually.
(2) Details of the modified vehicle operating status are sent to the cloud server.
(3) Details of the modified vehicle operating status are sent to the client application at the mine site and displayed on the screen.

The response time, defined as the time taken for these three steps, was measured. Also, the acceptable response time for dispatchers using the cloud FMS was set at 2 s or faster based on research into how long websites take to respond to user operations and what impression this creates[1].

Results

Fig. 5 shows the measured response times for the typical FMS operation. The response time became much longer when the VPN and new FMS functions added for the cloud implementation were included (indicated by "VPN and new FMS functions" in the figure). While these techniques are essential for operating a WAN over the Internet, they have a major negative impact on the response time. However, when Hitachi's distinctive WAN acceleration technology was incorporated (indicated by "VPN, new FMS functions, and WAN acceleration" in the figure), the mean response time for the typical FMS operation was reduced to about one-third of the previous value, and the maximum to about one-eighth. As a result, the response time was brought down below the acceptable limit for dispatchers using the system, demonstrating the effectiveness of the WAN acceleration technology.

CONCLUSIONS

This PoC project provided information about the technical viability of the cloud-based FMS. While a number of issues were identified that need to be resolved before a commercial service can be introduced, the work also provided an indication of how these can be overcome. Hitachi intends to market the service to customers and is actively preparing for introducing it commercially.

A developing trend at mining companies in recent years has been the use of information technology (IT) to make improvements in management efficiency.

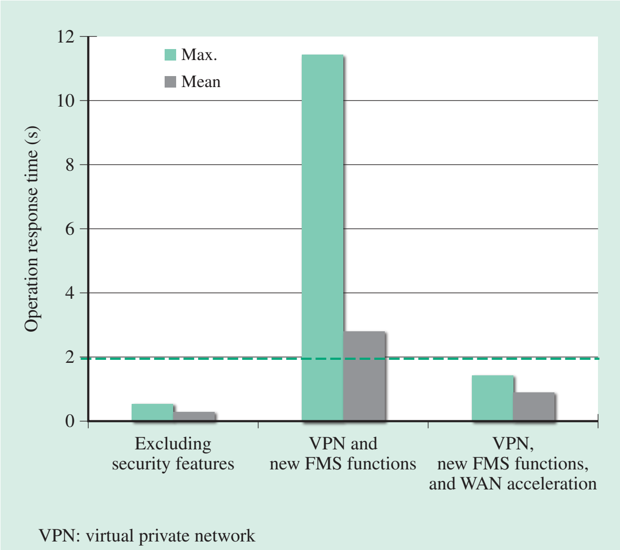

Fig. 5—Response Time between Canada and Japan for Typical FMS Operation in Proof of Concept Project.
Use of WAN acceleration technology shortened the response time for a typical FMS operation, bringing it under the acceptable limit for system operation by dispatchers.

Hitachi plans to offer smart information services to the mining business by seeking to fuse IT with operation technology (OT). Since the FMS server collects mine operation and management data, Hitachi also believes that it can identify the hidden challenges faced by mining companies and offer further business improvements by analyzing this data. Hitachi will continue to offer services with high added value from a customer's perspective.

ACKNOWLEDGEMENTS

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(1) "Powers of 10: Time Scales in User Experience," Jakob Nielsen, October 2009, http://www.nngroup.com/articles/powers-of-10-time-scales-in-ux/

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