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AN INFORMATION SYSTEMS APPROACH TO THE PROACTIVE MANAGEMENT OF SUBSCRIBER IDENTIFICATION MODULES IN INDUSTRY

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ABSTRACT

The Industry 4.0 paradigm focuses heavily on decentralisation, modularity and interoperability. These principles form the foundation for an effective Industry 4.0 ecosystem. The South African heavy industry still relies heavily on the traditional approach to centralised monitoring and control. Various Industry 4.0 initiatives have however been proposed and implemented in the heavy industry sector. For these initiatives to operate effectively, a stable network layer is required to facilitate reliable data transfer. To achieve data transfer over large geographical distances, most industrial information systems make use of mobile cellular networks, which implies the use of subscriber identification modules (SIMs) and supporting hardware such as network routers. The mismanagement of SIM cards can however result in excessive communication costs, which can in turn hamper the effectiveness of wireless data transmission. This paper presents a comprehensive information and asset management system to assist with overall SIM card management. The system allows for the accurate analysis of communication costs and ensures transparency both in the financial domain and in the physical domain. Results in this paper illustrate the effectiveness of this system in isolating communication anomalies that result in excessive data costs. The results show that the system can improve the quality and reliability of wide-area wireless telemetry and maintain indirect expenses that are associated with industrial information system communications. The proposed system assisted in reducing overall wide-area wireless communication cost with approximately 62%.

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1. INTRODUCTION

The term Industry 4.0 is a relatively new concept that is still considered to be in its infancy. Industry 4.0, initiated by the German government and presented at the Hannover Trade Fair in 2011, aims to address growth challenges in the European manufacturing sector [1]. The primary objective of the Industry 4.0 paradigm is to promote digitisation and integrate technological collaboration between various industrial systems [2]. For Industry 4.0 initiatives to be successful, various principles such as decentralisation, real-time production, modularity and interoperability need to be integrated into traditional methods of production [3].

The South African heavy industry, such as the mining and steel industry, still makes use of traditional centralised approaches to monitoring and control of production and assets [4]. This makes a full shift to decentralised and autonomous monitoring and control infeasible since the infrastructure to support Industry 4.0 initiatives must still be incorporated into the current industrial architecture. Various Industry 4.0-related initiatives and methodologies have however been proposed and implemented in the South African heavy industry. These initiatives mostly focus on indirect support and service delivery and includes condition-based maintenance systems, energy management information systems, automated bill analysis systems and remote monitoring and maintenance systems [5–8].

A fundamental component required to facilitate Industry 4.0 is the “Internet of Things” (IoT) to achieve its main goals [9]. The interconnection of individual devices allows for the transmission and reception of data. Data gathered by individual devices can then be used for intelligent decision-making purposes. This layer of intelligence, realised by IoT, allows devices to operate collectively in order to achieve predefined goals [10].

The fundamental component to the systems mentioned above is the communication network used to relay raw data from industrial sites to decentralised storage and computing infrastructure. To achieve data transmission, these systems make use of wide-area wireless telemetry networks, such as mobile cellular networks [11]. To utilise mobile cellular networks for data transmission and reception, subscriber identification modules (SIMs), as well as related hardware systems such as network routers, must be implemented at each remote industrial endpoint [12]. Mismanagement of these modules can result in additional expenditures and network instability, which in turn can effectively hamper the quality and reliability of Industrial IoT (IIoT) information systems discussed above.

Based on the context and challenges discussed above, the objective of this paper is to present and emphasise the value of an information and asset management system for SIM cards used by existing IIoT applications. To achieve this objective, the following sections will:

- present an architectural overview of industrial information systems in the context of the Industry 4.0 domain;
- discuss key challenges that can hamper the network layer quality and stability of industrial information systems;
- introduce a comprehensive information and asset management system to address SIM management; and
- analyse results of the information and asset management system to emphasise its value in industry.

2. AN OVERVIEW OF INDUSTRIAL INFORMATION SYSTEMS

This section aims to introduce an architectural overview of industrial information systems. A generic description of industrial information systems is first presented, after which two information system examples are provided to highlight critical points in the overall operation of these systems.

Industrial information systems typically follow an input-output service delivery model. For these systems to provide valuable feedback for decision-making purposes, data must first be provided from various sources. Raw data is then stored and processed in a decentralised storage and computing environment, after which information is relayed to visual dashboards for user notification purposes. Figure 1 gives an overview of the operation of an industrial information system.

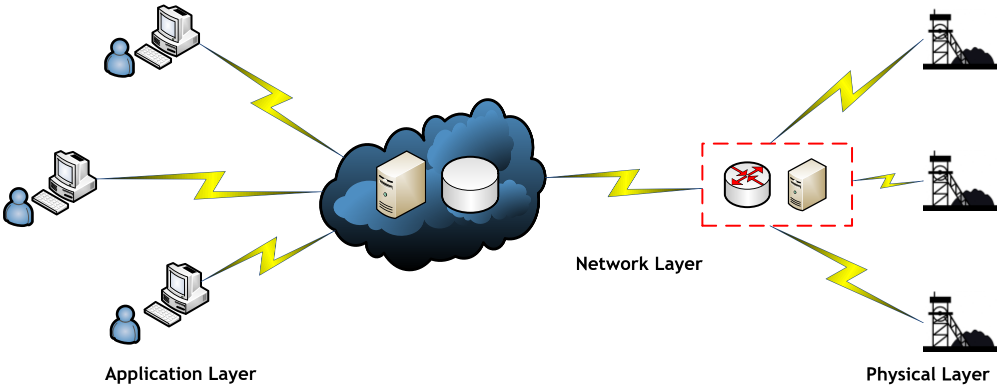

Figure 1: An overview of an industrial information system.

An industrial information system can be divided into three main parts namely, the physical layer, the network layer and the application layer. The collection of raw data takes place in the physical layer. Various sensors and actuators can be used to perform this task, but it is also possible to make use of an existing industrial supervisory control and data acquisition (SCADA) system to collect data.

The data obtained from industrial endpoints must then be transmitted to a decentralised storage scheme for data processing and storage. Cloud-based systems are used to allow for decentralised accessibility. Wide-area wireless communications, such as the Global System for Mobile communication (GSM), is used to transmit data to the cloud-based facility. This requires industrial GSM routers to be installed at industrial endpoints. Each router must also be fitted with a SIM card for connection to a mobile service provider network. Various works in literature emphasise the importance of wide-area wireless communications in IoT applications [11, 13–16]. Without a stable network layer, industrial information systems will be rendered inoperable.

Processed data can be relayed to users at the application layer. From here, system statuses can be viewed and informed decisions can be made. The decentralised nature of the storage and processing subsystem allows users to gain access without being restricted to certain geographical locations. All users are provided with system credentials for security purposes. Figure 1 illustrates a basic overview of a typical industrial information system. Two examples of existing systems in industry are provided below. An architectural overview of each system is given. Limitations and benefits of each system are also presented.

2.1 Example A: An Energy Management Information System (EMIS)

Goosen et al. [7] proposed a comprehensive energy management information system with the objective of providing industry with the ability to comply with various energy management standards, legislation and incentive structures. The system facilitates data collection and storage processes, as well as data analysis methods to provide users with accurate energy reports. Input data is provided to the system from external metering parties, the state-owned electricity utility Eskom, as well as direct input from industrial SCADA systems. Accurate energy reports are then provided as output. The energy reports can be viewed in document format, or the data can be viewed on real-time electronic dashboards. Figure 2 below gives an operational overview of the EMIS.

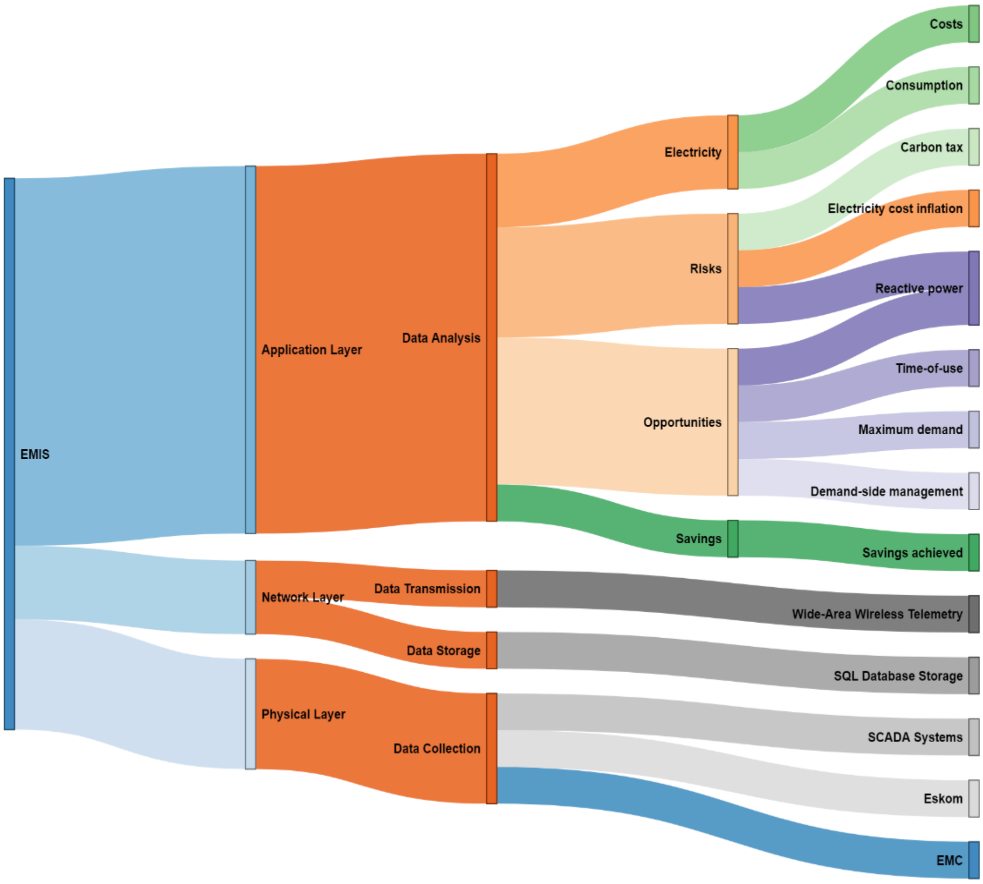

Figure 2: An operational overview of an EMIS (adapted from [7]).

The system proposed by Goosen et al. [7] provides an efficient and time effective way of allowing energy consumers to track their energy consumption and compare it to historic profiles. This system promotes decentralisation and is easily expandable. Goosen further expanded this system by incorporating an automated process where electricity bills are analysed [6]. This further improved the robustness of the EMIS and provided energy consumers with valuable information. The EMIS relies heavily on the GSM network for data transfer. Should intermittent connectivity issues present themselves, the EMIS will effectively be offline. The quality and stability of wide-area wireless communications is therefore considered to be a critical component to the effective operation of this system.

2.2 Example B: A condition-based maintenance system

Van Jaarsveld et al. [8] proposed a condition-based maintenance system with the objective of providing industry with the ability to accurately determine in real-time fashion the status of vital assets, such as pumps, compressors and fridge plant units. This system follows a similar approach to that of the EMIS proposed by Goosen et al. Only one source of input is used, which is the industrial SCADA system. Various status and efficiency parameters are monitored, such as vibration characteristics, temperature levels and trip counters. Data is transmitted in real-time fashion to a decentralised processing and storage unit, after which the processed data is relayed to visual dashboards. The transmitted data is processed for exception reporting, as well as "Safe, Caution, Risk, Failure" (SCRF) assessments. Figure 3 below provides an operational overview of the condition-based maintenance system.

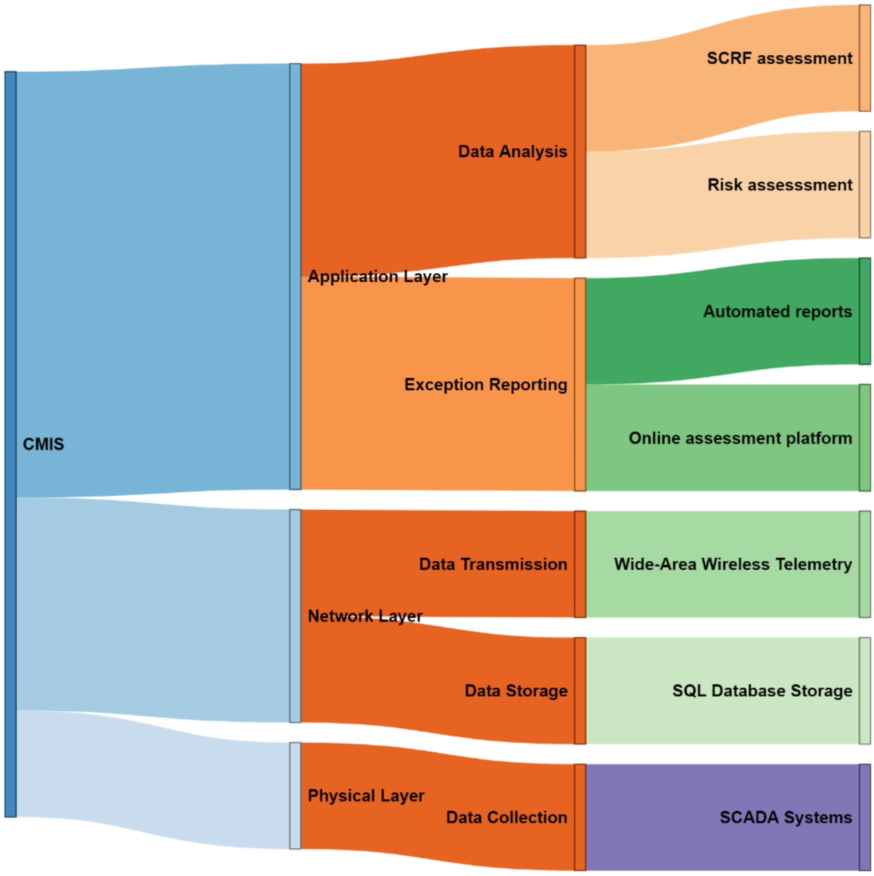

Figure 3: An operational overview of a condition-based maintenance system (adapted from [8]).

The system proposed by van Jaarsveld et al. [8] provides a unique and effective way of allowing industry players to know the operational status of critical assets. This improves maintenance processes and prevents unnecessary capital expenditures. As with the EMIS discussed above, this condition-based maintenance system also relies heavily on the GSM network for data transfer. Intermittent connectivity will hamper the effectiveness and reliability of this system. Emphasis must therefore be placed on the quality and reliability of the network layer.

2.3 Summary

This section aimed to provide an overview of industrial information systems. An industrial information system consists of three layers: the application layer, the network layer and the physical layer. The use of the GSM network and Internet Protocol technologies for Machine-to-Machine (M2M) communication and industrial wireless telemetry is a broadly accepted method for achieving connectivity and can therefore be considered as a key enabler for Industry 4.0 applications [10, 17–19]. Two examples of industrial information systems were presented. Both systems utilise the GSM network for wide-area wireless telemetry. The network layer is the backbone of an industrial information system. The quality and reliability of the network layer is therefore crucial for industrial information system stability. Based on the information discussed above, there is a need for a comprehensive information and asset management system that ensures transparency in the management of SIM units and other related network layer equipment. This system must ensure the stability in network layer communication and keep communication costs at a minimum.

3. CHALLENGES THAT DISRUPT DATA TRANSMISSION

Several challenges exist that inhibits the ability of industrial information systems to relay critical data in a real-time fashion. Mismanagement of SIM cards, the mismanagement of GSM routers on site and general hardware failures are among the few challenges that can result in intermittent connectivity. These challenges are discussed below and examples are provided.

3.1 Hardware failure

The most common challenge present in the network layer of industrial information systems is hardware failures. Industrial GSM routers are required to facilitate data transmission from site to cloud infrastructure. No transmission is possible if hardware failure occurs. Examples of router hardware failure include on board electronic failures, as well as power supply failures. In both cases, the router must be retrieved from the industrial site and a new router must be requisitioned to replace the defective unit. Replacing a router results in communication downtime, which is unacceptable in the context of mission-critical information systems. Hardware failure occurrences is however inevitable and proactive measures must be implemented to prevent interruptions in data transmission. A solution would be to incorporate network layer redundancy where more than one router is utilised for data transmission purposes. This however has cost implications, both on the hardware side as well as on the bandwidth side.

3.2 SIM card mismanagement

The mismanagement of SIM cards is also a key concern that can hamper network layer stability. For industrial GSM routers to relay data, they must be connected to the backbone network of a mobile service provider. As discussed in Section 2, SIM cards are used to facilitate this uplink. The mismanagement of these modules can result in additional expenses, either in the form of new mobile broadband contracts that need to be acquired, or purchasing of additional data bundles for existing mobile broadband contracts. Mismanagement can also lead to potential theft of both routers and SIM cards. It is therefore required to accurately monitor monthly data contract bills on a consistent basis. Monthly expenses must be analysed to determine the current state of individual modules. The bills must then be compared to the operational status of router units to determine whether these modules are crucial to information system operations or an unnecessary expense.

3.3 Router mismanagement

Router mismanagement often occurs with the repositioning of equipment. One of the prominent parameters that can directly be affected by router repositioning is network signal strength. A low signal strength results in intermittent connectivity. Remote industrial locations often have weak spots in the wireless network. It is therefore crucial to first perform an investigation to determine the optimal positions where GSM routers will have maximum signal strength. Interference on site can also hamper the signal strength of a GSM network router. This should be considered when determining the best location for network equipment. To ensure that no defective router is provided to an industrial site, accurate asset management procedures must be implemented that provide details of the status of all equipment. Router theft is also a key concern that can disable the network layer of an industrial information system. GSM routers must always be installed in locations with restricted access and these locations should be recorded for future reference.

3.4 Summary

This section presented several challenges that can disrupt the transmission of data in an industrial information system. Table 1 below summarises the main causes and provides examples that are related to the listed challenges.

Table 1: A summary of the challenges that can disrupt data transmission in an industrial information system.

Challenges that disrupt data transmission	
Challenges	***Examples from industry***
Hardware failure	• Power supply failure • On board electronic failure • Antenna failure
SIM card mismanagement	• Theft • Failure to analyse costs and budgets
Router mismanagement	• Repositioning of routers • Issuing of defective routers • Theft

4. A COMPREHENSIVE INFORMATION AND ASSET MANAGEMENT SYSTEM

Based on the sections above, a comprehensive information and asset management system is required that facilitates the effective management of SIM cards in industry. The information and asset management system can be divided into two main functional blocks. The general management block serves to link various SIM cards to industrial sites or personnel. The module management block identifies individual SIM units and serves to provide cost and administrator details of individual SIM cards. This allows for a cost and budget analysis to be conducted. The following sections describe each functional block in detail.

4.1 Module management

The module management subsystem focuses primarily on providing accurate cost analysis functionalities based on the provided input data. Figure 4 gives an overview of the module subsystem.

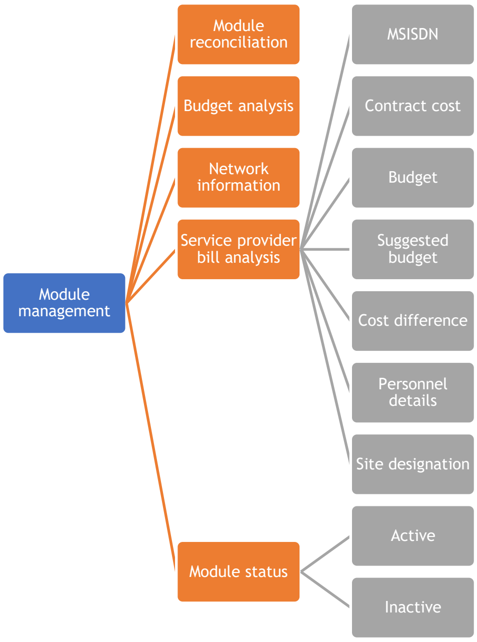

Figure 4: An overview of the module management subsystem.

For the subsystem to provide accurate cost analysis results, data contract invoices, as well as mobile service provider summary sheets must be provided as input on a monthly basis. In addition to cost analysis functionalities, the module management subsystem includes a module reconciliation section that reconciliates individual SIM cards with the corresponding module IP address. The system uses the mobile service provider summary sheet to update all MSISDN numbers with the corresponding IP address. The module reconciliation section will relay all mismatches to the user. The module management subsystem also displays network information for all SIM cards. This information includes the mobile service provider name, the contract type, and the network IP address that is linked to the module.

The cost analysis functionality relies on a separate service provider bill analysis section. The service provider bill analysis section uses the data contract invoices as input and extracts the module MSISDN number and the monthly expense for that module. This data is then compared to a suggested budget. From this comparison, a cost difference can be calculated to determine the usage condition of the module. If the module cost exceeds the suggested budget, the module is flagged as a negative expense and further investigation must be done to determine the nature and possible reason for exceeding the budget. In most cases, the sending of short message system (SMS) messages is the reason for exceeding stipulated budget values. Industrial information systems usually issue alarms via SMS to relevant personnel. Since data contracts do not cover SMS costs, an additional value is levied on the monthly contract amount.

4.2 General management

The main objective of the general management subsystem is to link a SIM card to a user. Figure 5 gives an overview of the module subsystem.

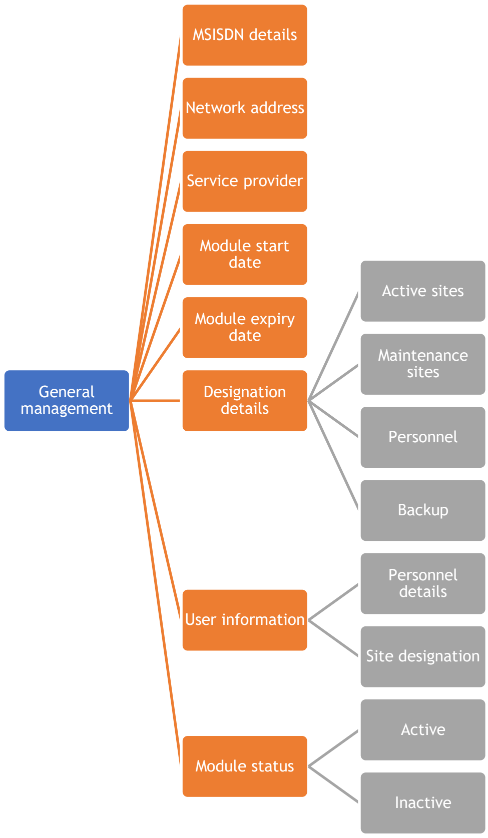

Figure 5: An overview of the general management subsystem.

The user can either be personnel or an industrial site. Personnel often require SIM cards for remote monitoring and maintenance of site equipment and systems. A SIM card with a designated IP address allows a project engineer to securely access on-site servers from a remote location. Modules that are allocated to industrial sites are utilised for data transmission purposes and forms an integral part of the network layer of industrial information systems. The general management subsystem lists module details such as the MSISDN number, the network address, the mobile service provider and the module activation and expiry date.

In addition to the information listed above, the general management subsystem also links group information to SIM cards. The purpose of the group information is to accurately indicate where the module is in use. The options that are available include active sites (sites where industrial information systems are currently active), maintenance sites, personnel and backup. Maintenance sites usually require modules to assist with remote monitoring and maintenance purposes. The general management subsystem also contains user information. If a module is labelled as a personnel module, the user information section will contain the personal details of the user, usually the name and surname, of the user. If the module is labelled as a site module, either an active site or a maintenance site, the site designation is provided. The site designation includes the industrial client group name, as well as the area of operations. Finally, the module is labelled as active or inactive. All modules issued either to personnel or to industrial sites must be in an active state.

The information and asset management system presented in this section allows for the effective management of SIM cards. The primary benefit of this system is the automated cost analysis functionality. Results of this functionality is presented below.

5. RESULTS

The information and asset management system presented in Section 4 above has been implemented on an existing telemetry network that sustains the network layer of multiple industrial information systems. These information systems are actively used by industrial client groups in the Republic of South Africa. The results presented below in Figures 6 to 9 are cost analysis results based on monthly data contract costs. An Energy

Services Company (ESCo) is responsible for maintaining the communication uplink to the different industrial client groups.

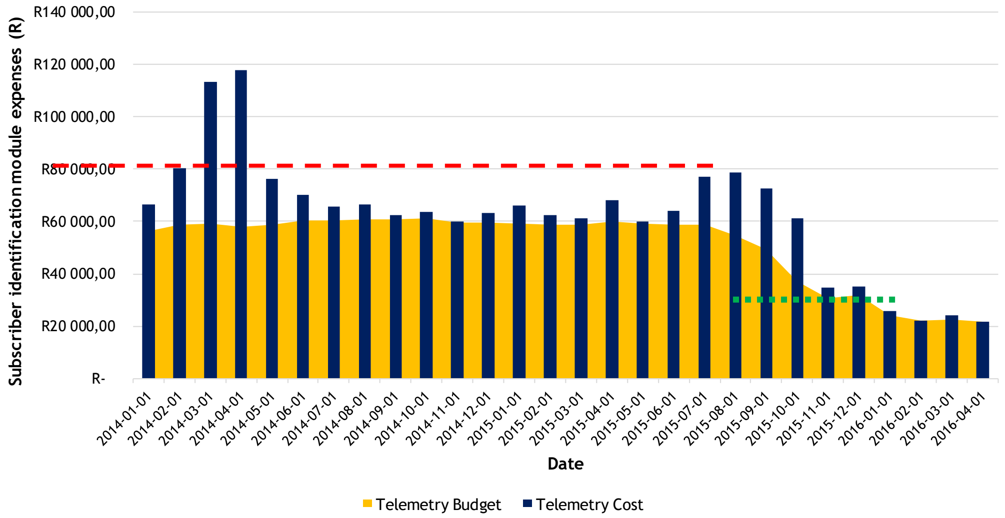

Figure 6: A cost analysis of existing SIM cards in circulation for information system operations.

Figure 6 represents a global cost analysis in South African Rand of sustaining telemetry uplinks to multiple industrial client groups. The actual cost per month is shown by the bar chart and the budgeted value is shown by the area chart. Multiple crossover points can be seen, where the total cost for the month exceeded the budgeted amount. This is because multiple SIM cards exceeded their monthly data limit. This resulted in out-of-bundle data rates coming into effect, which further increased the communication costs for the applicable months. The information and asset management system also assisted in the identification of SIM units on industrial sites that do not require any monitoring and maintenance. These SIM units were marked for decommissioning, which led to the decrease in the overall telemetry cost illustrated in Figure 6. The dashed line represents the average communication costs which equates to an amount of R71,698.93. After decommissioning unused and unnecessary cards, the average communication cost dropped to an average amount of R27,287.48, which is illustrated by the dotted line. This signifies a decrease in overall communication cost of approximately 62%.

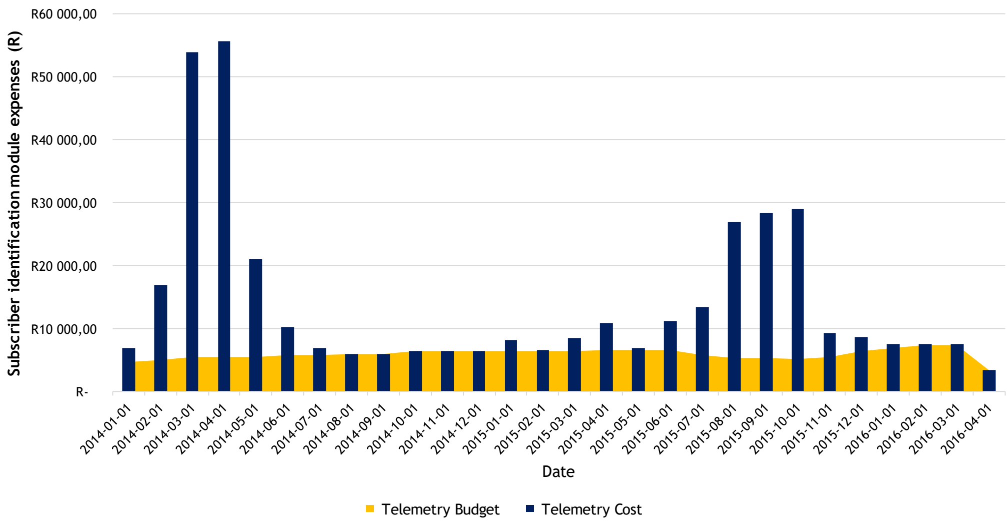

Figure 7: A cost analysis of SIM cards in circulation for a specific pumping scheme.

Figure 7 shows a specific cost analysis that was applied to a single industrial client group that was responsible for the operation of a water pumping scheme. The SIM cards utilised for sustaining the telemetry of the pumping scheme project exceeded the budgeted amount. The information and asset management system effectively allowed the ESCo to isolate the cause for excessive data bundle expenses seen in Figure 6. An individual cost analysis of the water pumping scheme telemetry network isolated the water pumping scheme network as the main cause for going over-budget. An investigation was launched by the ESCo to determine the exact cause for excessive data usage in both instances and the issues were rectified.

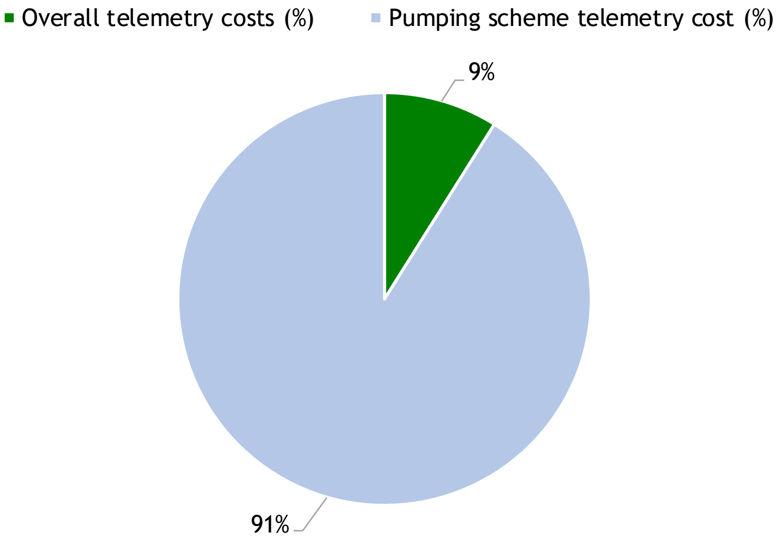

Figure 8: A cost comparison between overall telemetry costs and the telemetry cost of a pumping scheme network with exceptional data usage.

The proposed information and asset management system also allows for weight analyses to be done on different industrial client groups. Figure 8 illustrates the total weight of the water pumping scheme during the excessive data usage periods. The cost of maintaining the water pumping scheme telemetry network clearly outweighs the combined cost of other industrial client groups. This analysis can be used as a risk metric to determine the status of the telemetry network of a specific industrial client group. By doing a weighted analysis, excessive data usage can be highlighted and pinpointed to an industrial client. Investigations can then be initiated to determine the cause of excessive usage.

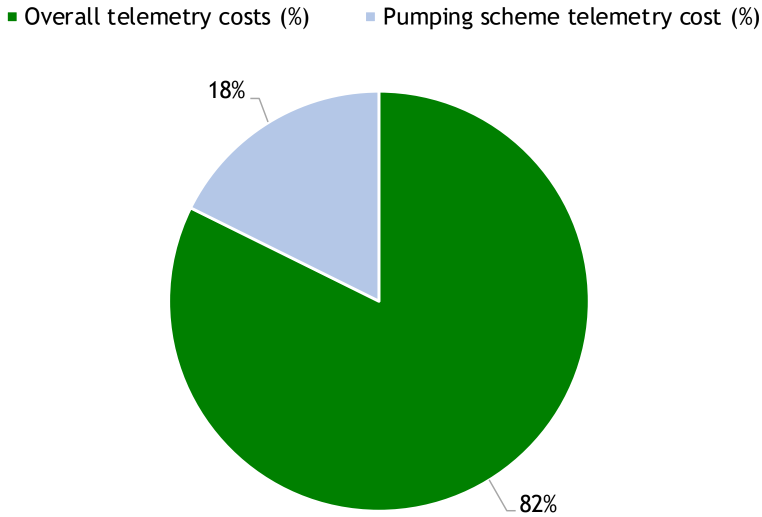

Figure 9: A cost comparison between overall telemetry costs and the telemetry cost of a pumping scheme network with normal data usage.

Figure 9 illustrates the same detailed cost analysis represented by Figure 8 however, this cost analysis was executed in a period where normal data usage was present. The total cost to maintain the telemetry network for the water pumping scheme is a mere 18% compared to the combined telemetry costs of all industrial client groups. This confirms that the telemetry uplink for a specific client is operating within acceptable budget parameters.

6. DISCUSSION OF RESULTS

A review of existing systems from literature and industry shows that there is a need for a comprehensive information and asset management system to address the management of SIM cards in industry. This system forms an integral part of the network layer of any Industry 4.0 information system that utilises the GSM network for real-time wireless data transfer. The information and asset management system proposed in this paper allowed for accurate cost analyses to be executed on SIM contracts. The system automatically generates these profiles based on billing invoices provided as input. The results presented in the previous section clearly shows the value of the system. The automated cost analyses can provide valuable insight into the health of the network layer and it can identify communication anomalies that has a direct effect on the cost of maintaining a wide-area wireless telemetry uplink.

The system proposed in this paper will ensure that industrial information systems, such as remote monitoring and maintenance systems proposed by Yang et al. [20] and condition-based maintenance systems as proposed by Van Jaarsveld et al. [8] will always be able to maintain real-time communication, whilst keeping communication costs at a minimum. In addition to the pumping scheme case study presented in the previous section, the system also identified SIM cards that were subject to theft. Module theft is usually flagged by excessive data costs. One investigation showed that a module linked to a router that was not operational still showed excessive data costs. An on-site investigation revealed that an unauthorised SIM swap was done with the replacement SIM being defective. The system proposed in this paper approaches network layer maintenance and stability from a cost and budget point of view. Not only does this improve the quality and reliability of wide-area wireless telemetry, but it also maintains indirect expenses that are associated with industrial information system communications.

The system is currently implemented as a standalone desktop system. This implies that the system can only be used locally. To increase operational and management efficiency, this system must be incorporated into existing information systems. An example would be to incorporate this system into the EMIS proposed by Goosen et al. [7]. This would not only allow industrial client groups to view telemetry cost analyses online, but it will also allow for the incorporation of these cost analyses into generated reports. This integration will expand the reach of the system and will allow clients to take responsibility of the communication costs.

7. CONCLUSION

The network layer is the backbone of any industrial information system. In the context of Industry 4.0, most information systems rely on wide-area wireless telemetry to achieve data transmission and decentralised storage and processing of data. The GSM network is currently an acceptable method to achieve this. Challenges are however present that can hamper the effectiveness of industrial information systems. These challenges include the mismanagement of hardware devices, mismanagement of SIM cards and hardware failures.

This paper presented an information systems approach to the management of SIM cards utilised in industry. The system consists of two main foundational blocks which allows for automated cost analyses to be calculated. Cost analyses contain actual expenses as well as budgeted values, which allows for budget comparisons to be made. Weighted analyses are also possible which assists in determining exceptions where communication anomalies are present.

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