Heikki Saha*, Tampere University

An improved IoT GW and configuration approach for mobile mining machine applications

Abstract: Typical IoT systems have been based on dedicated sensor networks. Gateways have been designed to route to server the entire communication message by message, without any processing. Further, automatic discovery of sensors has often been used. Data buffering has been used to cope with temporary communication failures only. Modern mining equipment contain electronic control systems, which provide various kinds of data for monitoring. In each site there may be numerous kinds of equipment, each providing different data as different sets. Especially in underground mines, there are areas without any communication network available due to a harsh conditions. This paper presents a new GW concept, which has intentionally been designed to provide a flexible connectivity to various equipment, networks and servers. Intentionally selected data will be extracted into a source independent format. Data buffered by the GW may be sent to the remote server, when a connection exists. Configurability requires well defined management processes to result reliable operation. This paper presents process examples for three major alternative connections, J1939 fleet management, CAN-based superstructure network and a CANopen sensor network. Field tests proved, that the presented GW concept reached the defined targets. The presented configuration processes improved getting the GWs configured without errors.

Keywords: IoT, IioT, gateway, configuration, mining

***Corresponding Author: Heikki Saha:** Dr., E-mail: heikki.k.saha@tuni.fi

1 Background

A set of physical objects – ''things'' – that send data and communicate with a network was called first time as a term of the Internet of Things (IoT) in 1999 by the MIT [1]. Industrial IoT (IIoT) may be defined integration of internal and external data, which means typically collecting process data from the actual control system and supplemental extra sensors and combing the data in the server [2] [3]. Different requirements apply to IoT and IIoT by means of environmental protection and interfacing [2]. Modern distributed control systems use embedded networks, "fieldbuses" for sharing the control system internal data inside the systems [4]. Similar networks are also in use in mobile assets, but may be called differently, e.g. "automotive networks" [5]. Typical use cases for IIoT data include production process, asset usage and service monitoring and optimization as well as invoicing [2] [4] [6].

Mining operations consist of multiple tasks – drilling, charging, exploding, secondary breaking, scaling, loading, hauling and reinforcing following each other and dedicated equipment are required in each task [7]. Typically such means the use of different kinds of equipment from multiple vendors, which leads into further challenges regarding fleet wide production process and condition monitoring systems.

Modern equipment contain distributed electronic onboard control system, e.g. trucks [5], with a standardized network interface for fleet management [8], which is a typical interface to obtain various kinds of remote monitoring data. In addition to the mandatory FMS (fleet management system) data, equipment vendors may provide optional data [9] as vendor specific sets. Some truck vendors provide similar communication also by so called BBM (body builder module) interface, which is intended for superstructure integration. Additionally, there may be one or more control networks dedicated for superstructure, which may need to be connected. Reliable installation of supplemental sensors has been found to be challenging [2].

Depending on mining method, production areas may vary and be in use for short periods. Thus it does not make any sense to build communication infrastructure covering the entire production areas [7]. There is typically an excellent infrastructure in the fixed areas of the mine, in which the data may be sent to the network. The networks available in the mines are company specific, from which a managed Internet connection is available through firewall. The networks contain business critical data, why communication is strictly constrained due to security and privacy reasons. Thus, the companies prefer to keep the server's master database strictly under their own control. As a result, each company may use different server framework and further use different application programming interface (API) for interfacing.

In underground mines, cellular networks are typically provided in very limited areas such as service areas, offices and lounges. Main underground communication medium is a WiFi. Cellular networks exist underground, but are more widely used for IIoT in surface mines. However, there may exist random blind spots.

Direct internet connection of an individual sensor is difficult to implemented in a proper way, especially with constrained resources [10]. A gateway (GW) is a device integrating sensors with heterogenous interfaces to a cloud platform over an available network connection [11] [4] [12]. In addition to the data routing, a GW may filter, preprocess and buffer the data [13] [12]. Due to the central role of the GW and its configuration in the IioT systems, GW behavior and related configuration management are in the main scope of this paper.

2 Aims

To develop and evaluate a new IIoT GW concept with characteristics: Smart and passive kind behavior; Fully configurable data reception for each supported protocol; Interface and protocol agnostic internal data model; Configuration data management for each supported protocol; Flexible local data buffering; Server- and network agnostic, plugin-based uplink.

3 Materials and methods

The most commonly used GW concepts were reviewed from the literature and compared with the requirements of mining applications. A new GW software supporting CANopen, raw CAN and J1939 was developed according to the identified requirements. The developed SW is hardware agnostic and thus tested first in a PC with Windows 10 and then in an embedded HW running Ångström Linux. Field testing was performed first in few assets and later number of assets was increased. Configuration workflow with conversion tools from corresponding standard network projects were developed.

4 Results and conclusions

The developed GW enabled an efficient adaptation of various kinds of assets to a back-end infrastructure. Implemented abstraction of information into signal samples and forwarding of the selected signals only enabled optimal use of the constrained communication resources from the field to the back-end. Typical configuration inconsistencies were avoided by relying on the standard processes and description formats of the selected network types. Computer aided generation of GW configurations from the validated communication descriptions lead into error free conversions and efficient deployments of heterogenous fleets.

5 Bibliography

[1] Ding J., Nemati M., Ranaweera C., Choi J., IoT Connectivity Technologies and Applications: A Survey, IEEE Access VOLUME 8, IEEE, 2020

[2] Strauß P., Schmitz M., Wöstmann R., Deuse J., Enabling of Predictive Maintenance in the Brownfield through Low-Cost Sensors, an IIoT-Architecture and Machine Learning, IEEE International Conference on Big Data (Big Data), IEEE, 2018

[3] Poulter A. J., Cox S. J., Enabling Secure Guest Access for Command-and-Control of Internet of Things Devices, IoT Journal, Volume 2, Issue 2, MDPI, 2021

[4] Tsiknas K., Taketzis D., Demertzis K., Skianis C., Cyber Threats to Industrial IoT: A Survey on Attacks and Countermeasures, IoT Journal, Volume 2, Issue 1, MDPI, 2021

[5] Recommended Practice for Control and Communications Network for On-Highway Equipment, J1939-01, SAE, 2000

[6] Brous P., Janssen M., Herder P., The dual effects of the Internet of Things (IoT): A systematic review of the benefits and risks of IoT adoption by organizations, International Journal of Information Management 51 (2020) 101952, Elsevier, 2022

[7] Matikainen R., Bäckström C., Heiskanen R., Koski V., Sundquist P., Valtakari U., Kaivos- ja louhintatekniikan käsikirja, Vuorimiesyhdistys Ry., 1982, 802 p. (in finnish)

[8] FMS-Standard description, Version 04, ACEA Task Force HDEI/BCEI, 13.10.2017

[9] Vehicle Application Layer, J1939-71, SAE, 2006

[10] Kang B., Choo H., An experimental study of a reliable IoT gateway, ICT Express 4 (2018) 130–133, Science Direct, 2017

[11] Yacchirema D. C., Palau C., Smart IoT Gateway For Heterogeneous Devices Interoperability, IEEE LATIN AMERICA TRANSACTIONS, VOL. 14, NO. 8, IEEE. 2016

[12] Beniwal G., Singhrova A., A systematic literature review on IoT gateways, Journal of King Saud University – Computer and Information Sciences 34 (2022) 9541–9563, Science Direct, 2021

[13] Zyrianoff I., Heideker A., Silva D., Kleinschmidt J., Soininen J., Salmon Cinotti T. and Kamienski C., Architecting and Deploying IoT Smart Applications: A Performance–Oriented Approach, Sensors 2020, 20, 84, MDPI, 2020

[14] Banaie F., Misic J., Misic V.B, Moghaddam M. H. Y., Seno S. A. H., Performance Analysis of Multithreaded IoT Gateway, IEEE INTERNET OF THINGS JOURNAL, VOL. 6, NO. 2, IEEE, 2019

[15] Pradeep P. Kant K., Con?ict Detection and Resolution in IoT Systems: A Survey, IoT Journal,Volume 3, Issue 1, MDPI, 2022

[16] Bröring A., Schmid S., Schindhelm C., Khelil A., Käbisch S., Kramer D., Le Phuoc D., Mitic J., Anicic D., Teniente E., Enabling IoT Ecosystems through Platform Interoperability, IEEE SOFTWARE 0740-7459/17/$33.00, 2017, IEEE

[17] Aziz A., Schelén O., Bodin U., A Study on Industrial IoT for the Mining Industry: Synthesized Architecture and Open Research Directions, IoT Journal, Volume 1, Issue 2, MDPI, 2020

[18] Sifakis J., System Design in the Era of IoT — Meeting the Autonomy Challenge, Electronic Proceedings in Theoretical Computer Science, Open Publishing Association, June 2018

[19] Gelenbe E., Nakip M., Czachórski T., Improving Massive Access to IoT Gateways, Jounal of Performance Evaluation 157–158 (2022) 102308, Elsevier, 2022

[20] Papcun P., Kajati E., Cupkova D., Mocnej J., Miskuf M., Zolotova I., Edge-enabled IoT gateway criteria selection and evaluation,Concurrency and Computation: Practice and Experience 2020;32:e5219, Wiley, 2019

[21] Kang B., Kim D., Hyunseung Choo H., Internet of Everything: A Large-Scale Autonomic IoT Gateway, IEEE TRANSACTIONS ON MULTI-SCALE COMPUTING SYSTEMS, VOL. 3, NO. 3, IEEE, 2017

[22] Abboud K., Li Y., Bermudez S., eSNAP: Enabling Sensor Network Automatic Positioning in IoT Lighting Systems, IEEE INTERNET OF THINGS JOURNAL, VOL. 7, NO. 10, IEEE, OCTOBER 2020

[23] Khaled A. E., Helal A., Lindquist W., Lee C., IoT-DDL —Device Description Language for the ''T'' in IoT, IEEE Access, VOLUME 6, IEEE, 2018

[24] Saha H., Automated workflow for generation of CANopen system monitoring GUI, Proceedings of the 17:th international CAN-Conference, CAN in Automation, 2020

[25] Fellmeth P., Löffler T., Networking Heavy-Duty Vehicles Based on SAE J1939, Technical Article, Vector Informatik GmbH, 12p