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Advancing Healthcare Research Through Live-Data Integration: Implementing IEEE 11073 and FHIR in Clinical Environment

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Abstract. The efficient direct integration of real-time medical device data is a promising approach to improve patient care enabling a direct and eminent intervention. This study presents a comprehensive approach for integrating real-time medical device data into clinical environments using the HL7® FHIR® standards and IEEE 11073 Service-Oriented Device Connectivity (SDC). The study proposes a conceptual framework and an opensource proof-of-concept implementation for real-time data integration within the Medical Data Integration Center (MeDIC) at UKSH. Key components include a selective recording mechanism to mitigate storage issues and ensure accurate data capture. Our robust network architecture utilizes Kafka brokers for seamless data transfer in isolated networks. The study demonstrates the selective capturing of real-time data within a clinical setting to enable medical device data for a down-stream processing and analysis.

Keywords. Data Integration, Interoperability, HL7 FHIR, SDC

1. Introduction

Enhancing data-driven methods through data integration is essential for advancing medical treatment. Currently, many approaches and models are tailored to static datasets, overlooking the continuous influx of real-time data from clinical environments, such as ECG or monitored vital signs [1]. A standardized integrating and data recording approach would enable medical device data for secondary use in downstream research projects and foster digital innovation within the clinical care setting [2].

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Integrating these data streams of medical devices poses challenges due to the diverse range of vendors, interfaces, and proprietary formats. Nevertheless, establishing a sustainable integration approach is indispensable for advancing healthcare practices and ultimately improving patient outcomes. Our junior research group IMPETUS is dedicated to extend the Medical Data Integration Center (MeDIC) [3] established at UKSH as part of the HiGHmed consortium [4] to enable the integration of multimedia data, regardless of the format or presentation in a standardized manner. The sustainable integration of medical device data would boost possible downstream research projects and enable an entirely new field of algorithm design within our clinical environment. This study presents a concept and implementation of a FHIR-based live-data integration for medical devices into the UKSH MeDIC.

2. Methods

To effectively identify and categorize the challenges that arise in the task of integrating live data from medical devices into our platform, we used an established catalog of requirements [5] and identified the most important requirements for data acquisition and processing of the live device data:

- R1. The system must be able to acquire data from different heterogeneous source systems.
- R2. The system must be able to acquire multimedia data from various domains.
- R3. The integration must be based on healthcare interoperability standards.
- R4. The integration must support international terminologies.

In addition to the identified requirements, the entire integration and data recording process must not interfere with clinical procedures or routine services. A complete recording takes up an enormous quantity of space where a direct benefit is not foreseeable. Selective recording must, therefore, be implemented.

3. Results

We proposed a concept and proof-of-concept implementation for live-recording medical device data directly from the source using IEEE 11073 service-oriented device connectivity (SDC) and forwarding the recording information in a standardized exchange format as FHIR instances for the integration within the UKSH MeDIC, as shown in Figure 1.

3.1. Device connectivity and network architecture

SDC allows a vendor-neutral point-to-point communication for medical devices in clinical settings and allows the exchange of data from a wide range of data-supplying systems for centralized use by clinical information systems. However, the SOAP-based design is not entirely suitable for data enrichment and the exchange between clinical information systems [8]. A translation of the SDC service data into the HL7 FHIR data model can facilitate the exchange between health information systems and downstream application contexts. SDC-capable devices communicate with each other using multicast network communication, causing a high volume of traffic. To reduce the configuration and management effort for the device communication and to ensure access security, the explicit discovery (where the service consumers search for services using UDP multicast probe messages), as well as the subsequent point-to-point communication, are isolated in the network. For this purpose, a new VLAN and L3 Interface (+DHCP) is created and connected to the MeDIC network. The network for the device-server endpoint communication is implemented as a separate isolated provider network. All SDC-capable devices are subscribed by a message broker provided by Dräger. The broker retrieves all device data in real-time and forwards the information to Kafka. A second downstream Kafka instance within the MeDIC infrastructure receives a live replica of the topics using the Kafka geo-replication function.

3.2. Standardized Data Recording using HL7 FHIR

The recording is based on the requirements for capturing real-time device data. To enable selective recording to reduce recording of unnecessary data, a user interface is implemented and available on Github [6]. The interface allows overseeing all incoming device data in real-time. If a relevant event occurs or an intervention is to begin, the recording can be started. The captured data is intermediately stored in a queue timestamp-ordered to counteract if messages are received in a non-synchronous order due to network lacks. When the selected recording time has elapsed, the data is split into 30-second intervals and processed as FHIR® observations, the interval length can be configured as required. Our FHIR® modeling is based on the Device-on-FHIR implementation guide [7], including the device tree definition using Device and the corresponding DeviceMetrics. Subsequently, the generated resources are transmitted to the FHIR store within the USKH MeDIC for down-stream analysis. The raw device data will be available in the Kafka topic for 24 hours if a recording needs to be extended or an operating error must be corrected.

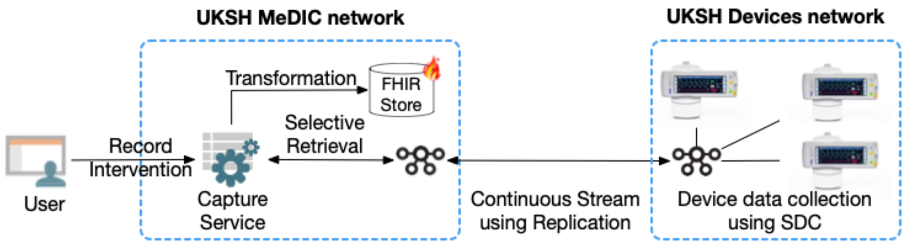

Figure 1. Conceptual overview of the presented approach: two network segments are required, as the SDC multicast communication must be isolated. Two Kafka brokers connect the networks and forward the data from the device network to the MeDIC network. A proposed user interface allows precise, selective recording of the data streams, whose are transformed and stored as FHIR observations.

4. Discussion

Our integration approach shows a working implementation of a live recording based on the existing IEEE 11073 SDC infrastructure and FHIR®. Incorporating SDC-compliant medical devices into a clinical environment can enable AI-driven clinical practices with numerous benefits [8]. This approach is based on a prior study [9] and continues by integrating the concept into the hospital network and storing recorded data in the UKSH MeDIC. The presented approach is based on IEEE 11073 SDC and promotes seamless interoperability, allowing different devices from various manufacturers to communicate effectively, thereby enhancing workflow efficiency and reducing integration challenges. Secondly, secure data communication facilitated by IEEE 11073 SDC ensures data integrity and confidentiality, which is essential for maintaining patient privacy and compliance with regulatory standards. The used software stack allows data integration from various medical device vendors independently into the MeDIC to meet the identified R1 and R2 due to the harmonized SDC data model. The current setting is tested with a multi-parameter patient monitor, a Dräger Infinity M540 – but more devices will be connected to the recording system. It is important to ensure that the devices are firstly SDC-capable and secondly that the routing to the multicast network does not affect the actual function of the clinical care setting. The use of Kafka as a message broker and gate between the isolated networks proves to be an effective solution [10,11]. The representation as FHIR® Observation provides structural and semantic interoperability and meets R3 and R4. FHIR® is an internationally used standard for healthcare data exchange, and the use of IEEE 11073 terminology ensures the interpretation and later reuse in downstream projects. However, the use of FHIR® yields a downside: information formatted in FHIR consumes additional storage space [12] in comparison to the original data. The presented approach introduces selective recording to enable precise and storage-saving data capturing.

5. Conclusions

The integration of live medical device data into clinical environments through efficient data integration methods is paramount for advancing healthcare practices and fostering digital innovation. This study outlines a conceptual framework and implementation for real-time data integration into the Medical Data Integration Center (MeDIC) at UKSH, leveraging HL7 FHIR® standards and IEEE 11073 SDC. By addressing challenges such as heterogeneous data sources and the need for standardized integration, this approach promotes interoperability, workflow efficiency, and data integrity within clinical settings. The use of selective recording mitigates storage concerns while ensuring precise data capture. Our next step is to integrate more devices into the recording system - but maintaining compatibility with clinical workflows will be crucial for maximizing its potential impact on patient care and downstream research projects.

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References

[1] Feng J, Phillips RV, Malenica I, Bishara A, Hubbard AE, Celi LA, and Pirracchio R, Clinical artificial intelligence quality improvement: towards continual monitoring and updating of AI algorithms in healthcare, Npj Digit. Med. 5 (2022) 1–9. doi:10.1038/s41746-022-00611-y.

[2] Obermeyer Z, and Emanuel EJ, Predicting the Future — Big Data, Machine Learning, and Clinical Medicine, N Engl J Med. 375 (2016) 1216–1219. doi:10.1056/NEJMp1606181.

[3] Kock-Schoppenhauer A-K, Schreiweis B, Ulrich H, Reimer N, Wiedekopf J, Kinast B, Busch H, Bergh B, and Ingenerf J, Medical Data Engineering – Theory and Practice, in: L. Bellatreche, G. Chernishev, A. Corral, S. Ouchani, and J. Vain (Eds.), Advances in Model and Data Engineering in the Digitalization Era (MEDI 2021). Communications in Computer and Information Science, Vol 1481, Springer, Cham, 2021: pp. 269–284. doi:10.1007/978-3-030-87657-9_21.

[4] Haarbrandt B, Schreiweis B, Rey S, Sax U, Scheithauer S, Rienhoff O, Knaup-Gregori P, Bavendiek U, Dieterich C, and Brors B, HiGHmed–an open platform approach to enhance care and research across institutional boundaries, Methods of Information in Medicine. 57 (2018) e66–e81.

[5] Kinast B, Ulrich H, Bergh B, and Schreiweis B, Functional Requirements for Medical Data Integration into Knowledge Management Environments: Requirements Elicitation Approach Based on Systematic Literature Analysis, Journal of Medical Internet Research. 25 (2023) e41344. doi:10.2196/41344.

[6] Hillmer T, and Ulrich H, IMIS-MIKI/mice-data-capture, (2024). https://github.com/IMIS-MIKI/mice-data-capture (accessed March 18, 2024).

[7] HL7.FHIR.UV.POCD\Home - FHIR v4.0.1, (n.d.). https://build.fhir.org/ig/HL7/uv-pocd/ (accessed March 4, 2024).

[8] Kasparick M, Andersen B, Franke S, Rockstroh M, Golatowski F, Timmermann D, Ingenerf J, and Neumuth T, Enabling artificial intelligence in high acuity medical environments, Minim Invasive Ther Allied Technol. 28 (2019) 120–126. doi:10.1080/13645706.2019.1599957.

[9] Andersen B, Ulrich H, Schlichting S, Golatowski F, Timmermann D, Ingenerf J, and Kasparick M, Point-of-Care Medical Devices and Systems Interoperability: A Mapping of ICE and FHIR, in: 2016 IEEE Conference on Standards for Communications and Networking (CSCN 2016), IEEE, 2016: pp. 1–5. doi:10.1109/CSCN.2016.7785165.

[10] Klar O, Klass M, Schneider G, Kenngott H, and Heinze O, Estimation and Monitoring of Operating Room Utilization by a Distributed Streaming and Analytics Architecture Deployed at Heidelberg University Hospital's Medical Data Integration Center, in: P. Otero, P. Scott, S.Z. Martin, and E. Huesing (Eds.), Studies in Health Technology and Informatics, IOS Press, 2022. doi:10.3233/SHTI220093.

[11] Kostov M, and Kaloyanova K, Real-time data integration in information systems using stream processing for medical data, Annual of Sofia University St. Kliment Ohridski. Faculty of Mathematics and Informatics. 110 (2023) 101–110.

[12] Bennett AM, Ulrich H, van Damme P, Wiedekopf J, and Johnson AEW, MIMIC-IV on FHIR: converting a decade of in-patient data into an exchangeable, interoperable format, Journal of the American Medical Informatics Association. (2023). doi:10.1093/JAMIA/OCAD002.