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# Realising horizontal and vertical health data-interoperability in low connectivity settings: the case of VODAN-Africa


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A challenge in digital health is interoperability as uncoordinated and fragmented digital health initiatives lead to lack of sustainability and reusability of solutions. Digital health solutions that create data of unknown provenance and merit prevent relevant interoperability and reuse[2]. An example is data generated from the past Ebola epidemics in Liberia, which is cited for the challenge of reuse if data is no longer findable, accessible, interoperable and reusable (FAIR)[1] and has made the data least available to the population that was affected by the disaster[2].

Interoperability is considered as the ability to interact and exchange data, services, and processes with clearly defined semantics and compliant to regulatory frameworks in the place where data is produced[3]. Lack of interoperability is a bottleneck to the digital transformation of healthcare[4]. VODAN-Africa tests this in low/no-connectivity settings and across different jurisdictions. This article discusses the realization of horizontal and vertical interoperability achieved across different settings.

## VODAN-Africa

VODAN-Africa curates patient data at point of service in clinics according to FAIR-guidelines. The community produces machine-readable federated data at residence. Data Ownership, Localisation of repositioning of data and Regulatory compliance in jurisdiction (OLR)[5] elevates federated interoperability for analytical purposes.

[1] Van Reisen, M., Oladipo, F., Stokmans, M., Mpezamihgo, M., Folorunso, S., Schultes, E., Basajja, M., Aktau, A., Amare, S. Y., Taye, G. T., Purnama Jati, P. H., Chindoza, K., Wirtz, M., Ghardallou, M., Stam, G., Ayele, W., Nalugala, R., Abdullahi, I., Osigwe, O., … Musen, M. A. (2021). Design of a FAIR digital data health infrastructure in Africa for COVID-19 reporting and research. Advanced Genetics, 2(2). Portico. https://doi.org/10.1002/ggn2.10050

[2] van Reisen M, Oladipo F, Stokmans M, Mpezamihgo M, Folorunso S, Schultes E, Basajja M, Aktau A, Amare SY, Taye GT, Purnama Jati PH. Design of a FAIR digital data health infrastructure in Africa for COVID-19 reporting and research. Advanced Genetics. 2021 Jun;2(2):e10050.

[3] Aerts A, Bogdan-Martin D. Leveraging data and AI to deliver on the promise of digital health. International Journal of Medical Informatics. 2021 Jun 1;150:104456.

[4] Mehl G, Tunçalp Ö, Ratanaprayul N, Tamrat T, Barreix M, Lowrance D, Bartolomeos K, Say L, Kostanjsek N, Jakob R, Grove J. WHO SMART guidelines: optimising country-level use of guideline recommendations in the digital age. The Lancet Digital Health. 2021 Apr 1;3(4):e213-6.

[5] Van Reisen, M. et al.: Connecting Health Data across jurisdictions through FAIR Data-visiting: Ownership, Localisation and Regulatory compliance (OLR). FAIR Connect - (Forethcoming)

VODAN-A Minimum Viable Product (MVP) creates semantic interoperability. The diversity of formats and standards in a medical information registry poses challenges in underlining the semantics of terminologies. It is challenging to achieve semantic level interoperability data exchange from multiple sources. Different terminologies may be used for the same concept in different standards which impedes conducting analytics from heterogeneous systems. This is a problem because community-defined data exchange formats serve the community itself, but not beyond that[6].

The architecture of VODAN-Africa (Figure 1) is a blueprint for the MVP deployed in 88 health facilities in nine African countries[3]. It enables us to FAIRify data and visualize it through internal and external dashboards, store machine-readable data and make data reposited in their jurisdiction accessible through a data visiting tool under well defined conditions. For data FAIRifcation, two approaches were followed. First, engineering of a tool that makes bulk upload possible to FAIRify existing data. It converts existing comma-separated data into RDF-triples. It reverse-models the vocabularies designed in the template and stores the resulting JSON-LD instance in MongoDB and RDF triples in AllegroGraph simultaneously. Two, collection of data at point of service from registries in clinics which are stored in JSON-LD format in MongoDB and in the form of RDF-triples in AllegroGraph. The FAIR-ready data in a triple store is exposed to data visiting algorithms. Different use-cases can then be envisaged, such as the export of the data to DHIS2. To this end, the MVP has used AllegroGraph as a triple store for querying using SPARQL. VODAN-Africa has implemented two different interoperability methodologies: vertical and horizontal interoperability[7].

## Vertical Interoperability

The MVP provides the ability to compute and send aggregated monthly reports to the HMIS systems which replaces manual computation of indicators. VODAN-A provides a solution to enable interoperability between a point of service application, the MVP

[6]https://www.medtecheurope.org/resource-library/interoperability-standards-in-digital-health-a-white-paper-from-the-medical-technology-industry/ - accessed Oct 08, 2022

[7] Wolfgang Kerber and Heike Schweitzer, Interoperability in the Digital Economy, 8 (2017) JIPITEC 39 para 1.

and health management information systems. DHIS2 provides a web API to accept data element values from the MVP, in Figure 2. The MVP prepares the statistics based on the data element report skeleton templates prepared in JSON format and posts the aggregated indicators into the DHIS2.

To create semantic interoperability, terminology services are required to perform the mapping of terms in the systems to interoperate. VODAN-A interoperates with DHIS2, using JSON standard reporting templates generated from DHIS2, which increases syntactic interoperability with point-to-point integration. To add flexibility and ensure security of communication during interoperability, having a separate enterprise service bus is envisaged as a micro-service. It has authentication, mediation, logging and management of interoperability services. Having such a layer can encourage and promote interoperability as other systems will delegate the task of interoperability to the dedicated service.

**Horizontal Interoperability**

Health clinics in the VODAN-Africa implementation network sign data sharing agreements to enable generation of knowledge at different levels to facilitate data and service interoperation. To address this issue, the community has created shared vocabularies, templates and other digital objects. As the system is interoperable by design, it creates horizontal interoperability. To realize seamless interoperability, VODAN Africa followed guidance of FAIR principal interoperability facets (I1 – I3). Thus, different health facilities are connected to create common terminologies which are displayed in a shared VODAN-Africa dashboard (Figure 3).

**Principle I1: (meta)data use a formal, accessible, shared, and broadly applicable language for knowledge representation**

To create a common understanding of digital resources, we used a globally understood language, Simple Knowledge Organization System (SKOS), to produce vocabularies. VODAN-A used CEDAR templates, using vocabularies created using SKOS and loaded into Bioportal. The templates are presented in JSON format which can be reused and interoperated by other systems. Data produced using the templates is represented in JSON-LD as well as triples in RDF.

**Principle I2: (meta)data use vocabularies that follow FAIR principles**

Reusability of data, by communication-specific agent and a generic agent, is the key consideration in this principle[8]. This was made possible through the use of controlled vocabularies. To this end, we created templates using CEDAR which utilize vocabularies we had hosted on BioPortal. VODAN-A has attempted to deploy OntoPortal locally, named as VodanaPortal, in a VM, deployed in a health facility to allow for the local repositing of data in the residence where the data is produced. As the terminology service in CEDAR is developed to work with BioPortal, adjustments were needed in the code-base to localize the data storing. Despite attempts to do so, the result was not satisfactory for technical reasons.

It was found that a challenge of working with remote ontology services was the issue of performance in low/no-connectivity settings, where data production was challenging and in places with no internet connectivity data production had become impossible. Some of the sites changed the templates removing the controlled vocabularies and replacing them with literals from which users can select. Through these solutions, the spirit of the principle is adapted to what is possible within the context of deployment. The issue was then addressed in a new architecture by making controlled vocabularies accessible from a local repository.

**Principle I3: (meta)data include qualified references to other (meta)data**

The semantic modeling was conducted by reviewing terminologies from the registry forms. VODANA-GENERAL terms were identified and stored on BioPortal. Each country has also defined its own templates, vocabularies, and types of (meta)data to be collected. A fully qualified reference is stored in the template JSON and JSON-LD instances to the classes, acronyms, schemas and related (meta)data information. Even metadata information for the terms used is stored using a unique IRI that can help in interpretation, query and visualization. This facilitates both human and machine agents to interpret and understand concepts in the same way.

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[8] A. Jacobsen, R. de Miranda Azevedo, N. Juty, D. Batista, S. Coles, R. Cornet, ... & E. Schultes. FAIR principles: Interpretations and implementation considerations. Data Intelligence 2(2020), 10–29. doi: 10.1162/dint_r_00024

To address issues of performance for low/no connectivity settings, a lightweight application was developed, using a new architecture (Figure 4), that can produce FAIR data using vocabularies that is accessible offline. Currently, it is being tested in health clinics in Tigray, Ethiopia, where there is a communication blackout[9]. To ensure principle I2, the templates are designed in CEDAR using vocabularies from BioPortal. The template JSON and the vocabularies in CSV format are downloaded from CEDAR and Bioportal, respectively, then loaded to the light MVP. The light MVP renders the templates parsing the JSON and loading the vocabularies offline. During data entry, the system gives an autocomplete feature for controlled vocabularies and keeps the IRIs of the terms. It produces and displays in JSON-LD and RDF. The system also stores the RDF triples in AllegroGraph. Statistics are then calculated and loaded on the internal dashboard and the external dashboard. Thiscreates potential for the development of further use-cases through data-visiting that includes low/no connectivity settings[10].

## Conclusion

VODAN-Africa is a FAIR-implementation starting FAIRification and exposing FAIR-ready data for visiting algorithms realising data-interoperability. The principles are technology agnostic and provide freedom to operate. An MVP was created to generate FAIR-compliant medical data, stored it in a federated manner on AllegroGraph and making the RDF-triplets available for visiting, using SPARQL-queries. Use of controlled vocabularies for low/no connectivity settings was tested and found to be feasible. Vertical interoperability has been tested with another platform, DHIS2, and horizontal interoperability was tested with two community dashboards. The test was successful; included different settings, including low/no connectivity settings. Ensuring that such data is curated as FAIR and Federated, AI-Ready data would accelerate the availability of inclusive, quality data-pipelines that

[9] Gesesew H, Berhane K, Siraj ES, Siraj D, Gebregziabher M, Gebre YG, Gebreslassie SA, Amdes F, Tesema AG, Siraj A, Aregawi M. The impact of war on the health system of the Tigray region in Ethiopia: an assessment. BMJ Global Health. 2021 Nov 1;6(11):e007328.

[10] Van Reisen, M., Oladipo, F., Mpezamihigo, M., Plug, R., Basajja, M., Aktau, A., Purnama Jati, P.H., Nalugala, R., Folorunso, S., Amare, Y.S., Abdulahi, I., Afolabi, O.O., Mwesigwa, E., Taye, G.T., Kawu, A., Ghardallou, M., Liang, Y., Osigwe, O., Medhanyie, A.A., Mawere, M.: Incomplete COVID-19 data: The curation of medical health data by the Virus Outbreak Data Network-Africa. Data Intelligence 4(4) (2022). doi: 10.1162/dint_a_00166

will enhance the application of machine-learning and future AI to discover meaningful patterns in epidemic outbreaks.

*Highlight the text to count the characters including spaces under Tools/Word count in the Google menu bar. A maximum of 10,000 characters is allowed.*

## Figure item(s)

Figure 1: VODAN Africa architecture for clinical data.

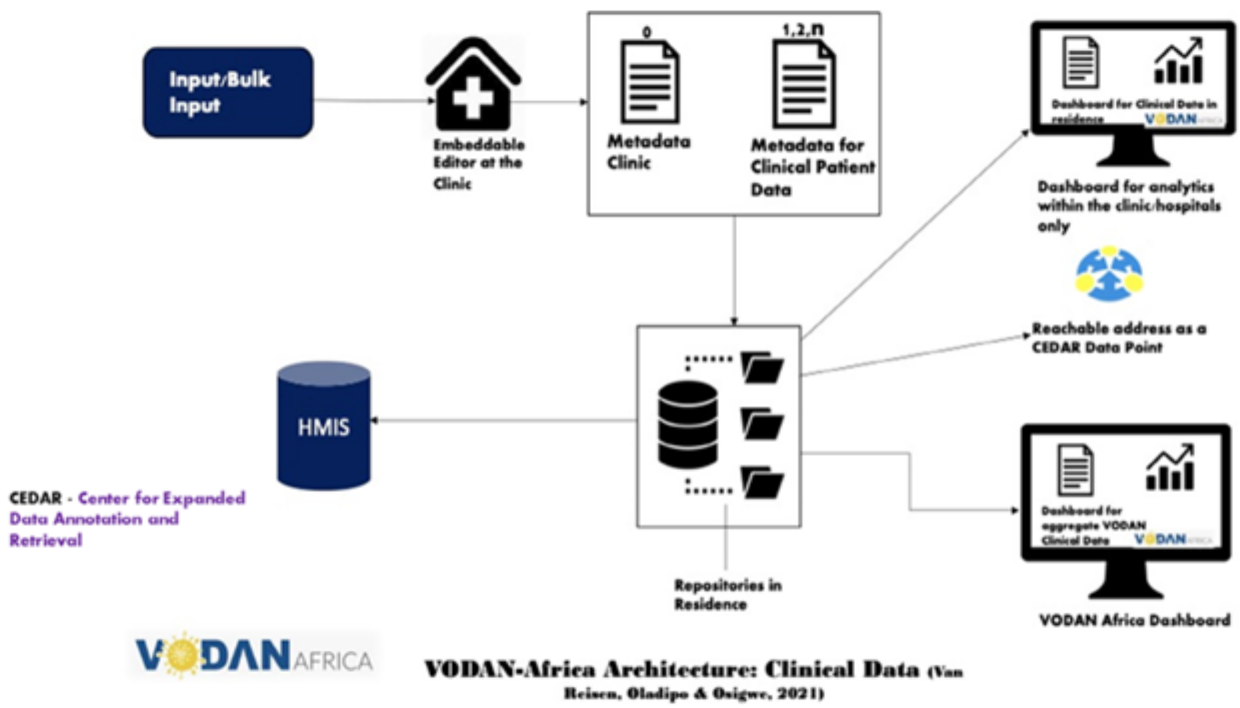


Figure 2: Interoperability between VODAN-A MVP and DHIS2

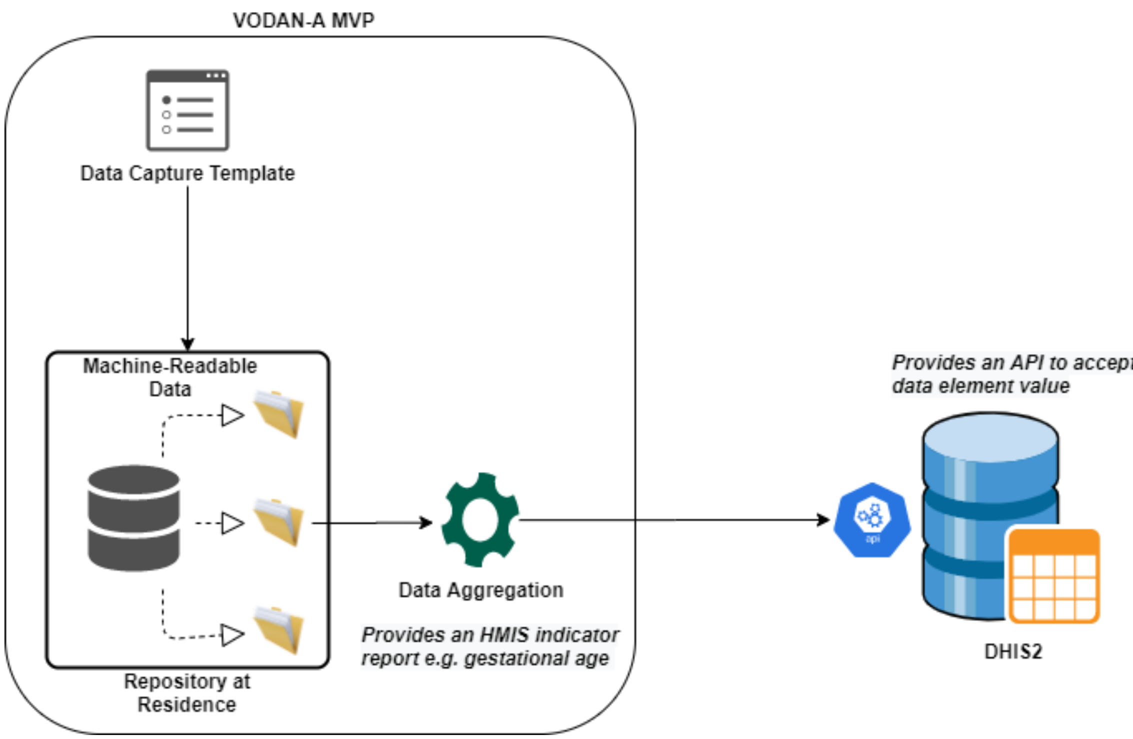


Figure 3: Interoperability across health facilities in VODAN Africa

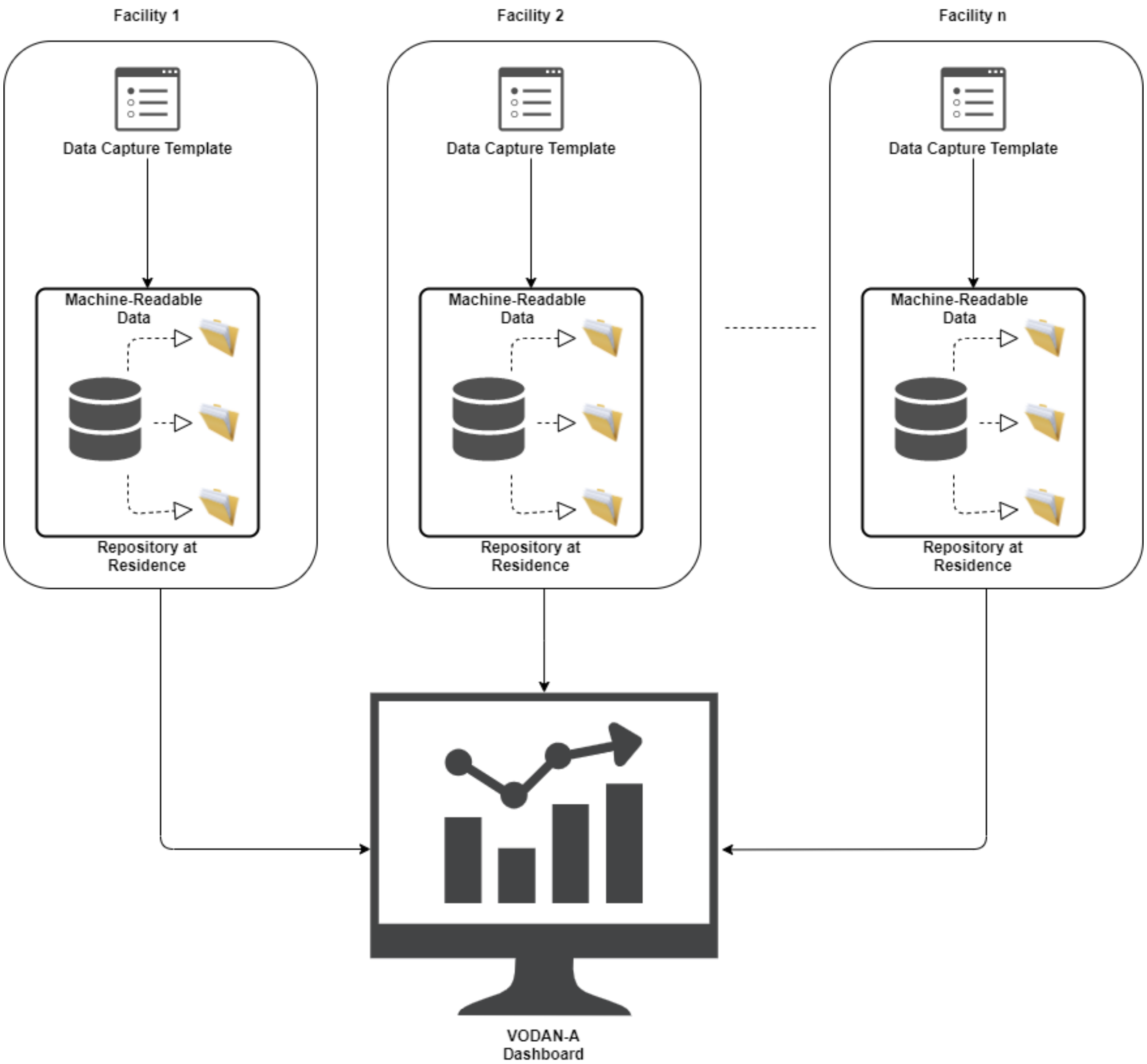
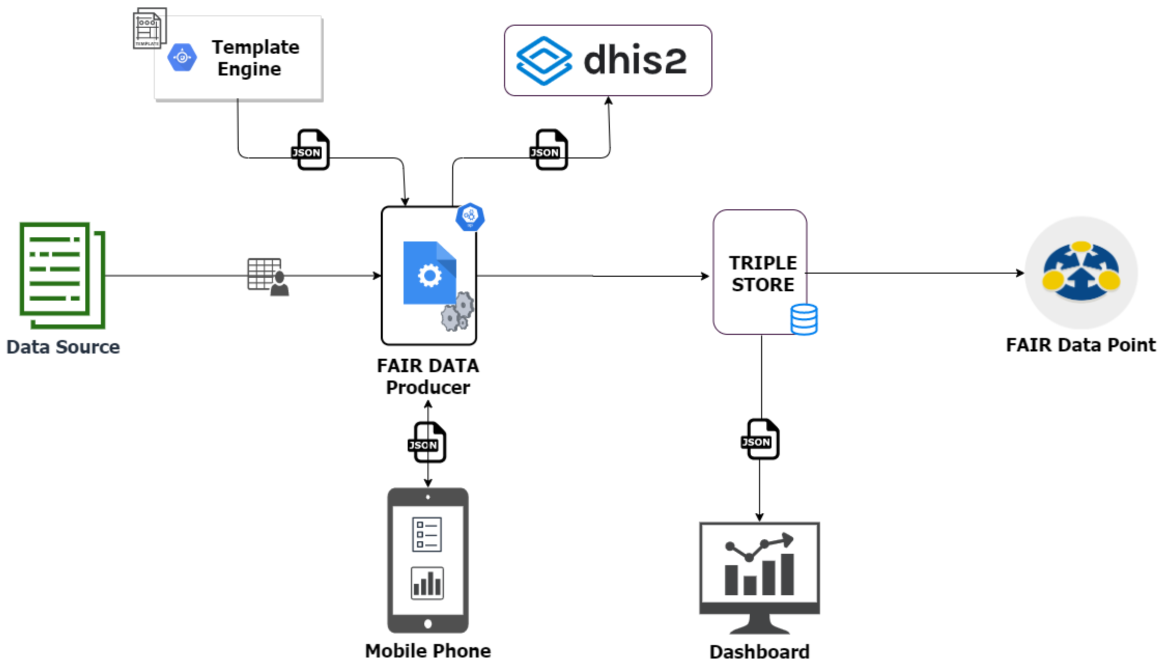



Figure 4: VODAN Africa Architecture for low resource and offline setting.




VODAN Africa Architecture: low resource and offline setting (Samson Yohannes & Getu Tadele)