Valkyrie:
A Distributed Service-Oriented Architecture for Coordinated Healthcare Services

[a] Terje Solvoll, [b] Conceição Granja, [c] Sonja Cassidy, [d] Øivind Solvang, [e] Ove Lintvedt

[a,b,e] Norwegian Centre for E-health Research
University Hospital of North Norway
Tromsø, Norway

[a,b,c,d,e] Faculty of Nursing and Health Sciences
Nord University
Bodø, Norway

[c,d] Department of Strategic ICT
Helse Vest IKT
Bergen, Norway

e-mail: [a]terje.solvoll@ehealthresearch.no, [b]conceicao.granja@ehealthresearch.no, [c]sonja.cassidy@helse-vest-ikt.no, [d]oivind.skeidsvoll.solvang@helse-vest-ikt.no, [e]ove.lintvedt@ehealthresearch.no

Abstract— **The Valkyrie project aims to address the increasing number of individuals struggling with mental disorders in Norway and the pressure this has placed on the healthcare system. The project focuses on the coordination of services and the need for information across clinical levels in the healthcare system. Valkyrie aims to provide access to quality care and reduce the adverse effects of mental disorders. The Valkyrie project will contribute to the United Nation sustainable development goals and enhance healthcare services in Norway by facilitating knowledge transfer, improving interaction across care settings, and providing new knowledge on digitalization and patient-centric care. The project aligns with the National e-Health Strategy and supports several priority areas of the e-Health Plan.**

Keywords-Electronic Health Records; Voice of the Patient (VoP); Coordination; Healthcare; Patient-centric Pathways; Service-Oriented Architecture (SOA); Virtual Health Record.

I. INTRODUCTION

The full coordination of health care services entails that the correct data is available to the right person at the right time, regardless of where the patient has previously received medical care. This concept is a critical objective in the Norwegian national strategy of "One citizen – One Journal" [1]. From an Information and Communication Technology (ICT) standpoint, this means connecting multiple Healthcare Information Systems (HIS) across multiple healthcare levels. The Valkyrie project responds to the challenge and will demonstrate its feasibility by making a technological prototype.

A prominent example of a target group in contact with multiple healthcare providers across the Norwegian healthcare system to complete their care plan is persons with mental disorders. The common use that a person with mental disorders makes of the Norwegian healthcare system is hospitalization, outpatient, and day services in specialist healthcare, as well as GP, emergency-, care-, social-, rehabilitation-, and day services from the municipality. In the current scenario, GPs do not have access to electronic Patient Health Data (ePHD) from the municipality services or specialist care. Only standardized documents are exchanged, which is insufficient for health professionals responsible for the patient. A WHO report revealed that persons with mental disorders in Nordic countries have a two- to three-times higher mortality rate [2]. The risk factors for this excessive mortality strongly relate to the service delivery, particularly regarding the lack of coordination and management of the health care services as the main contributors [2]. Furthermore, medical comorbidity is expected in this target group [3], where the majority suffers from at least one chronic medical condition requiring somatic care [4] in addition to their mental care. This target group´s demand for Norwegian healthcare, makes it an excellent case study for Valkyrie.

Norwegian Directorate of Health National Plan for Implementation of Patient Pathways [5] has identified challenges with the digitalization of the Norwegian healthcare sector, recognizing the need for more research to better use of ePHD. A need has also been identified for implementing new patient pathways for mental health, which improve the coordination between primary and specialist care [5][6]. However, the challenges of accessing ePHD across multiple HIS, and integrating it with patient-centric solutions to form complete pathways, threaten the chances of achieving the goals for patient pathways. We should clarify that the use of data from the patients' journals to support patient pathways is provided by the Norwegian Patient Journal Law Chapter 2 (§§7-10, 19) [7], as well as on the Patient Records Act and the Health Register Act [8] that explicitly points out that business boundaries should not hinder the sharing of health information.

It is of significant relevance for the "digital interfaces, robotics, and virtual environments" research area to establish an open and standard methodology to describe patient-centric pathways with a high level of granularity in a form that allows ePHD to become ubiquitous by being made available in multiple HIS across multiple settings. Thus, establishing the foundations for health care services coordination.

Valkyrie will model patient-centric pathways that guide a Virtual Health Record (VHR) outline. The VHR will be made available to the providers' HIS, thus making it possible to, when relevant, access a view of ePHD. Hence, all ePHD will

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become ubiquitous in facilitating health care services coordination. This paper will define the process of how to solve this in a real-life setting.

This paper is structured in five sections. Section one, this section, presents the introduction of the paper. In section two we present the state of the art, followed by a presentation of the Valkyrie solution in section three. Section four presents the discussion, and we end the paper with a conclusion in section five.

II. STATE OF THE ART

Research has shown benefits for patient-centric care, such as improved quality of life, increased adherence to treatment protocols, and reduced morbidity [9]. On the other hand, the current HIS are not designed to support integrated care delivery that spans multiple providers and settings at any health care level. ICT is set to play a significant role in coordinating healthcare providers who are often separated by time and space. However, introducing ICT into healthcare has proven challenging owing to the underlying complexity of healthcare processes and the number of actors involved in those processes [10].

A. Modelling patient-centric pathways

According to the Norwegian Directorate of Health [6], a pathway is a national standardized patient pathway with the aim to contribute to rapid diagnosis and treatment initiation without unnecessary waiting time. A patient-centric pathway is a structured care plan that combines national guidelines with local practices and patients' wants, needs, and preferences.

Healthcare delivery can be represented as a continuum that moves from the micro-level to the macro-level [12]. The macro-level represents system-level processes, such as patient flows through a hospital, while the micro-level represents processes at the individual patient care level. Although they are interrelated, the micro- and macro-levels require different modeling approaches owing to their different granularity levels.

Business process modeling has been used in healthcare to help represent healthcare processes so we can design systems to support those processes. Jun et al. [13] point out that a better application of process modeling is needed to provide safe, effective, timely, and patient-centric healthcare services. Process modeling (particularly simulation models) has helped evaluating and understanding healthcare processes at the macro-level by developing models such as those proposed by Granja et al. [14] for resource usage and radiology flows. However, micro-level modeling at the patient's level is far less advanced. Micro-level models require explicit details about the ePHD and communication flows across processes and healthcare providers. An example of micro-level modeling is the work of Malholtra et al. [15], who developed a comprehensive model of the providers, activities, and ePHD flows in the intensive care unit to identify, characterize, and reduce medical errors in that unit. Nevertheless, one shortcoming with their work is that it was ad hoc and did not use a formal modeling language or methodology, not easing the identification of specific indicators or best practices that can be considered for implementing such models and ensuring their scalability to other health domains.

B. Distributed Service-Oriented Architecture

When redesigning a healthcare system and design ICT to support it, we need to move from delivering individual products to delivering integrated services [11]. From the perspective of healthcare ICT, this means moving away from developing ICT for separate tasks (e.g., decision support, order entry) to developing integrated HIS that supports the continuity of healthcare delivery over time. The Service-Oriented Architecture (SOA) paradigm and its ability to connect multiple HIS across different settings is a candidate for developing integrated HIS to support healthcare services coordination across different settings. SOA was introduced in healthcare to help break down silos and monoliths by separating the interface and services from the content and business logic and exposing it as a chain of interrelated services, feeding into expectations of better communication and interoperability between healthcare organizations and patients.

The adoption of SOA and its healthcare principles is still slow when compared to other industries [12]. The reasons for this are linked to the also slow adoption of common standards and that SOA introduces a new type of complexity – if one service goes down, the whole chain of services breaks – which has led to more point-to-point integrations instead of using a separate process layer (e.g., enterprise service bus). Interoperability is still an issue, especially semantic interoperability [13], i.e., how to deliver the meaning and context together with the ePHD seamlessly across HIS [14]. More recently, an adaption of SOA has emerged, known as the Microservices architecture [15]. SOA and the Microservices architecture share the same ideas on exposing business processes as services. However, opposite to SOA, the Microservices architecture divides a monolithic application into multiple atomic services that run independently on distributed computing platforms, including distributed data stores.

C. Mental health as a case-study

In Norway, the yearly prevalence of mental illness ranges between 16 and 22% of the population [16]. Although most of these persons have not been in contact with the healthcare services [17], approximately 12.5% of the adult Norwegian population has a consultation in primary care related to psychological ailments, being that for specialist healthcare, the number of consultations is at 15% [16]. The fragmented organization of the health and social welfare services in Norway constitutes a major barrier to providing comprehensive, integrated, and coordinated services for persons in the target group.

Since 1999, the Norwegian healthcare sector has been through several reforms that rightly have focused on reducing the overall costs of healthcare [18][19], coordinating service across the different levels of healthcare [19][20], increasing patient engagement [20], and equal access to health care [18]. In early 2019, three generic patient pathways for mental health and substance abuse were implemented. Later the same year,

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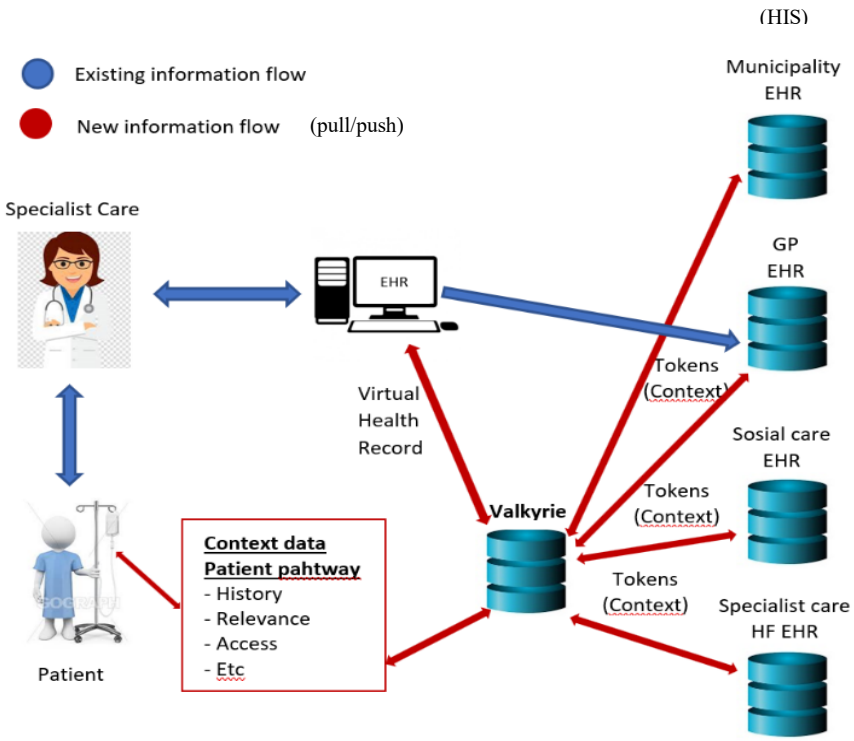

Figure 1: The Valkyrie solution: a simplified architecture

the government issued the first four specific clinical pathways [5]. Research on the implemented clinical pathways for mental health shows that nearly 70% of healthcare professionals believe the pathways, to a small extent or not at all, have contributed to more coherent and coordinated care, and 76% believe pathways, to a small extent or not at all, lead to more user participation and user satisfaction [21].

III. The Valkyrie Solution

To support collaboration between patients, their relatives, and health professionals, patient-centric pathways models are to be based on the Voice of the Patient (VoP) and verified information from experts explaining decisions or variances in the pathway [22].

Research has demonstrated the benefits of using ePHD to model clinical pathways to ensure it is derived factually and objectively from actual occurrences in the patient journey. Still, little research considers a combination of patient-centric design and data-driven to model patient pathways, and even less that approaches it as micro-level modeling. The Valkyrie approach to modeling patient-centric pathways draws on the Norwegian Directory of Health National Plan for Implementation of Patient Pathways [5]. However, it will use a combination of a patient-centric design and a data-driven approach to ensure the micro-level modeling of the patient-centric pathway is derived from actual ePHD occurrences across multiple healthcare levels.

A. *Distributed Service-Oriented Architecture*

The Valkyrie architecture, Figure 1, supports patient-centric pathways for mental health by delivering a Virtual Health Record (VHR) driven by the requirements of the pathway.

To populate the VHR, each participating HIS pushes a token, encrypted using a public key provided by Valkyrie, whenever an event is recorded in the system for any patient, illustrated in Figure 1. The token carries the patient identifier (unencrypted) and a small set of metadata about the event, including an identifier sufficient to locate the event in the source HIS, and the clinical coding descriptive of the event. The encrypted tokens are transmitted to the Messaging Engine (Valkyrie), which filters the tokens based on the directory of Legitimate Relationships between Valkyrie and individual patients. Tokens for patients without a legitimate relationship are immediately discarded; tokens for patients with a legitimate relationship are stored in the Encrypted Token Store within the Valkyre solution.

To create the Virtual Record Outline for a specific patient, Valkyrie will gather, from the Encrypted Token Store, all encrypted tokens for the patient and decrypt them using Valkyrie's private key, allowing Valkyrie to form the Virtual Record Outline as a timeline of events, some of which may be relevant to the patient-centric pathway. Once the relevance of the events is confirmed in the Resolver (Valkyrie), the Resolver uses the metadata about the event source and locator to request the event view through the Pull Interface of the relevant HIS. When a new patient is added to Valkyrie, messages are sent through the Pull interfaces to each of the

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participating HIS, requesting the push of a set of encrypted tokens for the entire historical record of that patient.

The Blockchain will store the chain of events and status in the patient-centric pathway, together with necessary encrypted metadata, to serve the requests from all the actors. The Microservices will handle logins and message services with push and pull mechanisms through API gateways and interfaces, and enable a scalable and flexible architecture for new, added services when needed. To ensure the correct and relevant presentation of information for each patient and healthcare professional, we will develop an ontology-based semantic layer.

IV. Discussion

The number of persons struggling with mental disorders who need treatment has increased faster than the Norwegian healthcare system was prepared for, putting intense pressure on both primary and specialized care, and the number of clinicians needed to treat them. There is an urgent need to provide this patient group with access to quality care as early as possible to reduce the well-documented adverse long-term effects of such disorders. These patients are less likely to complete their education. They have significant problems getting into the labor market, resulting in higher sick leave costs, various social security costs, the burden of disease, and increased mortality [23]. To complete their care pathway, each person in the target group is in contact with multiple settings across Norwegian healthcare, inevitably resulting in ePHD being distributed in multiple HIS. Valkyrie will enable knowledge transfer across business boundaries and levels of care and facilitate more effective interaction through the patient care pathway.

Valkyrie shall contribute to attaining the objectives of the UN sustainable development goal 3 to ensure healthy lives and promote well-being at all ages, and goal 8 to promote inclusive and sustainable economic growth, employment, and decent work for all.

The Valkyrie project will also contribute new knowledge for the digitalization of the healthcare sector in Norway, specifically relating to HIS scalability, integration, and semantic interoperability. One can identify critical factors for successful implementation by investigating barriers and facilitators and how to cope with them. This knowledge can be used for further implementation of the model and other health interventions; It provides knowledge of the usefulness of a government-initiated action aimed at developing new ways of organizing integrated services. This knowledge will help to enhance healthcare services and improve the quality of care. The Valkyrie project will contribute new knowledge on how the patient´s view of their care pathway is described using standard and open modeling languages and methodologies to ensure scalability and inform the development of patient-centric pathways.

Valkyrie supports two of the three main objectives of the National e-Health Strategy [6], the National e-Health Action Plan 2017-2021 [24], and the strategy of One citizen – One journal [1]. Further, Valkyrie will contribute to five of the six priority areas of the e-Health Plan 2019-2022 [4], namely, tasks 1.1, 2.1, 3.1, 5.1, and 6.1.

V. Conclusion

With the increasing number of individuals struggling with mental disorders and the pressure this puts on the healthcare system, the importance of the coordination of services and the need for information across clinical levels will become more important in the future. Providing access to important patient information and thereby quality care, can reduce the adverse effects of mental disorders and thereby facilitate knowledge transfer, improve interaction across care settings, and provide new knowledge on digitalization and patient-centric care.

The Valkyrie project will contribute new knowledge to the digitalization of the healthcare sector in Norway and support the objectives of the National e-Health Strategy, the National e-Health Action Plan, and the strategy of One citizen – One journal. Investigating barriers and facilitators of the project will provide valuable insights for further implementation and improvement of healthcare services.

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