

# Patient and Business Rules Extraction and Formalisation Using SVN and SBVR for Automated Healthcare

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## Abstract

*This paper describes advances in automated health service selection and composition in the Ambient Assisted Living (AAL) domain. We apply a Service Value Network (SVN) approach to automatically match medical practice recommendations to health services based on sensor readings in a home care context. Medical practice recommendations are extracted from National Health and Medical Research Council (NHMRC) guidelines. Service networks are derived from Medicare Benefits Schedule (MBS) listings. Service provider rules are further formalised using Semantics of Business Vocabulary and Business Rules (SBVR), which allows business participants to identify and define machine-readable rules. We demonstrate our work by applying an SVN composition process to patient profiles in the context of Type 2 Diabetes Management.*

## Keywords

Rule Extraction, SBVR, Type 2 Diabetes, Ambient Assisted Living, Service Value Networks

## 1. INTRODUCTION

Ambient Assisted Living technologies are widely regarded as an interesting option to help solve the demographic and economic challenges of the future associated with an ageing population (AALJP 2011). In Europe, the population over 65 is expected to become more than 30% of the total population by 2060 (Eurostat 2008). In Australia, we see similar numbers with an expected increase to 23% by 2056 (ABS 2009). The associated cost of the related increase in care needs is expected to place a significant burden on industrialised economies (Kleinberger et al. 2007). In order to abate the rising cost of healthcare, scenarios that involve home care and high degrees of automation are being explored and developed. In this paper we present a general framework that makes use of a number of currently available health service related resources to create a form of automated, sensor-driven healthcare in the context of Australian Type 2 Diabetes Management. Our Service Value Network (SVN) approach finds the optimal health service for a patient based on sensor readings in a home care context. On the patient side, we extract and formalise medical practice guidelines from the National Health and Medical Research Council (NHMRC). On the provider side, we extract service attributes and rules from the Medicare Benefits Schedule (MBS) listings with an application of SBVR on the business rules embedded in the MBS. This paper is organised as follows: Section 2 discusses the background and motivations to the research. Section 3 outlines the approach. Section 4 describes the outcomes with use of an example, followed by a discussion in Section 5, and concluding with Section 6.

## 2. BACKGROUND AND MOTIVATION

In this section we outline the main areas, components, and motivations of our approach. These are Ambient Assisted Living, the National Health and Medical Research Council medical practice recommendations, the Medicare Benefits Schedule health service listings, Service Value Networks, and Semantics of Business Vocabulary and Business Rules.

### 2.1 Ambient Assisted Living

Health service provision is expected to evolve towards cheaper, more automated models in the future. With the increase of the number of elderly people in industrialised nations, comes a high cost to the economy (Eurostat 2007, ABS 2009). From a financial perspective, the effect of an ageing population is further catalysed by the old age dependency ratio (OADR). This ratio represents the population older than 65 divided by the working age population supporting them. In Europe, the OADR is projected to increase from 25% currently, to 53% by 2060. In Australia, the OADR will increase from the current 20%, to 38% in 2056. This increase translates to only two or three people being able to support an elderly person compared to the current four or five. In Australia, the added effect of rural and remote healthcare further burdens the financial picture: a significant part of the population lives in remote and rural areas with more expensive access to healthcare services (AIHW 2012).

There are two major trends underpinning the transformation of healthcare in the future: location and automation. The provision of health services is increasingly moving towards home care systems, in which people with special needs are supported in the comfort of their own home. The automation of health services relates to replacing some human resources in the value network by automated services. Ambient Assisted Living (AAL) technologies can help provide autonomy to elderly and disabled people, allowing them to live at home individually for longer with an increased quality of life, whilst at the same time offering a model that is cheaper and more efficient to society. AAL typically takes place in a 'smart home' environment, with sensors and supporting infrastructure providing the ability to monitor and support patients remotely (Turner et al. 2009). In our case of Type 2 Diabetes management at home, two types of sensors can be used to remotely monitor the health of patients: blood pressure sensors for measuring hypertension, and blood glucose sensors (which can be part of continuous blood glucose monitoring systems) for measuring hyperglycemia. Lipids are measured as well for hyperlipidaemia in the context of diabetes, but can currently not be measured via remote sensors.

As a relatively young domain, AAL is facing a number of technological challenges (Kleinberger et al. 2007): (1) *Adaptivity*: systems need to monitor their environment and adapt themselves constantly. (2) *Natural interactions*: systems need to provide interfaces for users with varying needs. (3) *Heterogeneity*: systems are closed, standalone, and provided by different suppliers with diverging knowledge and technologies. (4) *Domain knowledge formalization*: domain knowledge that is difficult to formalize needs to be transformed for processing. (5) *Elderly stakeholders*: the main stakeholders of AAL have generally low degrees of computer literacy and variable degrees of mental clarity, alertness and memory function, creating interface constraints. (6) *Low acceptance*: systems that are marketed as solely assisting with health problems have low acceptance rates because of the social stigma associated with them. (7) *Integration of available technologies*: AAL systems and services are characterized by heterogeneity and disparate data sources, which offers integration challenges. (8) *Immaturity*: although it is generally expected that AAL will be a huge market, there is only limited knowledge about what the products will look like, what their economic viability will be, who will provide them, how they will integrate, etc.

In this paper we focus mainly on solving problems associated with AAL challenge 4, with an additional focus on challenges 3 and 7. By using a service value network approach to integrate the 'medical practice' side of healthcare with the 'business' side of it, we offer an integration of two healthcare realms and related technologies (Challenge 7). Following information and data are transformed into machine-readable assets that can be used in the context of automated healthcare: (1) on the medical practice side (or patient side), rules are extracted from the NHMRC guidelines and formalised; (2) on the business side (or provider side), services and service attributes are extracted and formalised into machine-readable, automated rules; (3) furthermore, business rules (or service provider rules) are formalised using SBVR, bringing to bear the 'rules of engagement' for the service providers when delivering services in the context of our AAL framework. In a sense, this type of straightforward integration using readily available data levels the playing field for service providers (Challenge 3). Because it can be assumed that each provider will claim to Medicare all performed services, a service network can be derived based on the claims providers make in conjunction with the service attributes and business rules. Finally, since our approach formalises necessary information ranging from the initial biological parameters (patient) to ultimate service delivery (provider), we contribute to the formalisation of the healthcare domain specifically in the context of AAL (Challenge 4).

## 2.2 National Health and Medical Research Council

The National Health and Medical Research Council (NHMRC) in Australia is a government body promoting the development and maintenance of public and individual health standards. It serves the functions of research funding and development of advice and draws upon the resources of all components of the national health system (including governments, medical practitioners, nurses and allied health professionals, researchers, teaching and research institutions, public and private program managers, service administrators, community health organisations, social health researchers and consumers) (NHMRC 2012). The NHMRC guidelines are developed by a team of health and medical field specialists, with the purpose of providing a general guide to appropriate practice. They are based on the best evidence at the time of development and provide a set of principles and recommendations to assist in decision-making. These are expected to be followed by the general practitioner/clinician, subject to their judgement and patient's preference in each individual case.

## 2.3 Medicare Benefits Schedule

The Medicare Program provides access to medical and hospital service for Australian residents. Medicare benefits or 'rebates' are expressed as a percentage of the total cost of a medical service, ranging from 75% to 100%. Benefits are claimed by service providers and patients and are reimbursed by the Australian Government. (Department of Health and Ageing 2011). The Medicare Benefits Schedule (MBS) is a comprehensive listing of all professional medical services reimbursed through the Medicare Program. Each health service has a unique ID number, a name, a description and the fee/benefit of that service in Australian dollars. The MBS can be consulted in document form, via a web interface, and in a downloadable xml format. Services are related to each other by explanations containing hyperlinks. The descriptions of services also contain business rules, i.e. constraints on the use of the services from both the patient and provider perspective (e.g. patient eligibility, service history, provider eligibility, cost constraints, etc.).

## 2.4 Service Value Networks

As opposed to value chains, which are sequences of activities each adding a part of the value to a production process, in SVNs value is co-created in a decentralized setting. A service value network is a flexible and dynamic web of enterprises and final customers who reciprocally establish relationships with each other for delivering an added-value service to a final customer (see Razo-Zapata et al. 2011, Hamilton 2004, Allee 2002, and Lovelock and Wirtz 2010). The key challenge of SVN composition is to automatically match and bundle relevant competences in a network such that they deliver the value (i.e. a service) required by a customer. SVNs are usually organized in different tiers: at B2C side, service providers aim to offer relevant competences in fulfillment of a customer need; at B2B side, service enablers support the technology space that can make these services possible (Basole and Rouse 2008); hence e-services. e3value (Gordijn and Akkermans 2003, Akkermans et al. 2004) is a well-known SVN composition approach. It features ontologies to analyse and model perspectives of customers and providers on service needs. Inspired by service marketing and management theory, the conceptualization of services focuses on value aspects, rather than merely computer-technical aspects as found in most service-oriented computing paradigms.

## 2.5 Semantics of Business Vocabulary and Business Rules

The Semantics of Business Vocabulary and Business Rules (SBVR) (Object Management Group 2008) is a standard developed by the Object Management Group (OMG) and is intended to serve as a basis for describing a complex entity such as a business in near-natural language. The fact that SBVR uses near-natural language allows business domain experts, rather than ontology and/or knowledge engineers to supply and define the business rules, business facts and business vocabularies. SBVR serves as a central framework for shared meaning between business actors, and allows these actors to describe all aspects of a business using shared concepts and formal logic, so that specifications can be understood by humans and processed by computers. Because SBVR is explicitly fact-oriented as well as rule-based, it is particularly useful for defining shared business concepts and 'rules of engagement' in business ecosystems or service networks with many, different, and often disparate participants.

# 3. APPROACH

In this section we describe the SVN composition process. We start off with a general overview of the SVN methodology and describe modifications to the e3value framework for application in the healthcare domain. We then elaborate on the formalisation process of medical practice guidelines, which allows for conversion of patient profiles into functional consequences that can be used in SVN composition. We then elaborate on the extraction, formalisation and mapping process of healthcare services for SVN composition. Finally, we elaborate on the application of SBVR for describing the business rules and related facts.

## 3.1 Overview

The goal of an SVN is to find an optimal service composition (supplier perspective) for a given customer need (customer perspective). In e3value, this is done via a method described in Gordijn et al. (2011), Razo-Zapata et al. (2011a), and Razo-Zapata et al. (2011b). The method consists of four subtasks as depicted in Figure 1: Propose, Verify, Critique, and Modify (Razo-Zapata et al. 2011c). In this paper we focus mainly on the propose aspect, however we will give a brief overview of the other aspects as well.

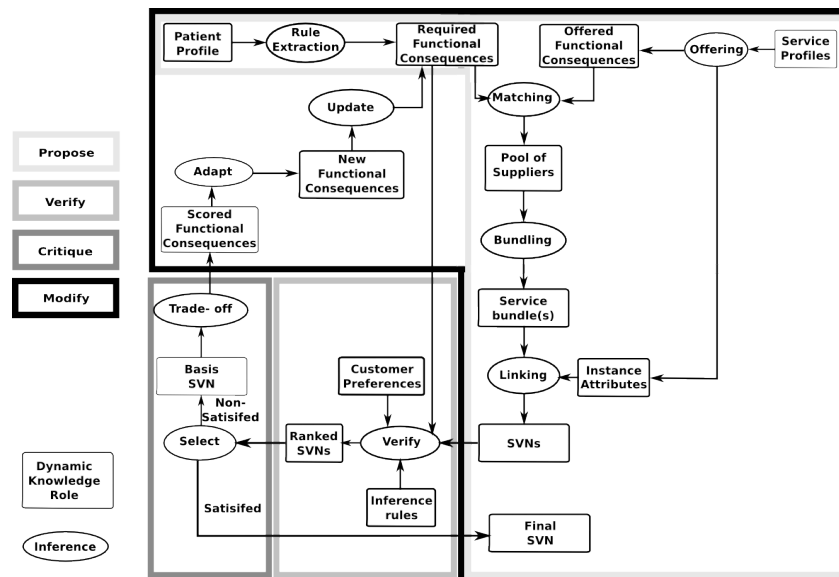


Figure 1: Service Value Network Composition

(1) In the **Propose** subtask a suitable value proposition and solution are proposed as a solution to a need. It involves the sub-processes of Laddering, Offering, Matching, Bundling and Linking. (a) *Laddering* is a marketing practice where marketers explore how customers link specific product properties to higher-level values. In SVNs, the process is used to transform customer needs into what is termed ‘functional consequences’ (FCs). FCs can be considered actionable items that can be satisfied by suppliers. Traditionally, FCs are derived from explicit customer needs. However, in many contexts, and especially those where end users have no clear idea, or insufficient knowledge, it is prohibitively difficult or unadvisable to have users explicate their needs (Meersman and Debruyne 2011, Meersman and De Leenheer 2012). In our approach we replace the laddering process with a more tacit approach involving an extracted rule base that acts on sensor readings and recommends FCs according to the rule base (see section 3.2: ‘Rule extraction and mapping’). Although the end user is still the recipient of the service, the translation of his or her needs to FCs is done outside of his or her grasp, i.e. in an ambient manner. (b) *Offering* is a similar process to laddering, but the process takes place on the supplier side: suppliers translate their offers (assets and competencies) to FCs as well in order to create a ‘common currency’ for matching. In our approach, we substitute this laddering with rigid mappings between services and FCs that have been validated by health domain experts. The reasoning behind this is that in a context of health services, a validation of the mappings between services and FCs is called for because of accountability and accuracy considerations, i.e. we need to make sure that the right value proposition and service are delivered according to agreed-upon medical practice recommendations. (c) *Matching* concerns the matching of customer with suppliers in terms of FCs, additionally constrained by medical practice considerations and customer preference on the customer side, and business rules on the supplier side. In our case study, the matching process is appended in favor of a direct mapping based on Business Rules. The matching process results in a pool of service providers. (d) *Bundling* is the process where meaningful combinations of services and service providers are made to satisfy the customer need. The output of this process is a set of proposed service bundles that describe B2C relationships in terms of value exchanges. Finally, in the (e) *Linking* stage we solve any B2B dependencies that might exist between various service providers.

The following subtasks are not the subject of this paper, but are discussed for the sake of being complete. (2) The **Verify** subtask refers to the process of verification if SVN designs satisfy functional requirements. Once the SVNs have been composed, the verification subtask determines (a) *whether* the SVN offers the required FCs and (b) *how* it fits the customer requirements. (3) The **Critique** subtask identifies the source of failure in case of unsuccessful design and allows for the designs to be improved before deployment. (4) Finally, the **Modify** subtask takes input from monitoring the SVN performance (customer preference, patient health status, performance monitoring, etc.) and allows for continuous improvements after initial deployment. We will now discuss our approach in extracting and formalising patient rules and services for use in the SVN composition process.

### 3.2 Patient rule extraction and mapping

For the patient rule extraction, we have focused on the utilisation of NHMRC guidelines related to treatment of patients diagnosed with Type 2 Diabetes. The NHMRC guidelines provide detailed pharmacological advice on

how to manage the patient's hypertension, hyperlipidaemia and hyperglycaemia in the light of their existing biological parameters and clinical data. We have focused on the summary of recommendations within the guidelines, where the majority of recommendations for a typical patient profile can be found. Any profiles that fall outside of the scope of typical medical practice are not part of automated processes within the framework (if unordinary profiles occur, human intelligence is required to select the best treatment based on the patient profile and medical state-of-the-art). We have formalised the NHMRC guidelines and recommendations related to hypertension (blood pressure control), hyperlipidaemia (lipid control), and hyperglycaemia (blood glucose control) in a machine-readable format that can be implemented within the proposed framework. This formalisation is in the form of IF-THEN rules, where the precedent of a rule indicates the set of preconditions that must hold, while the consequent indicates the treatment recommendation. All rules were verified and validated by domain experts. During consultations with the domain experts, the rules were further enriched to reflect a particular stage of the treatment and when more specific information was available it was added to the more general rules extracted (e.g. specific medicine used, and which medicine should/should not be used in combination with other medicine/treatment). This resulted in a total of 131 rules out of which 90 were related to blood pressure control, 21 to blood glucose control and 20 for lipid control. Note that if the characteristics of a patient satisfy the pre-conditions of multiple rules, then multiple recommendations for treatment would be provided within the guidelines. Note that henceforth we will use the general term *attribute* to refer to a set of measurements (e.g. blood pressure, glucose level etc.) or patient characteristics. In the formalization that follows, for simplicity purposes we assume that the set of conditions/measurement values of attributes from NHMRC guidelines and observed from patients are represented by either a true or false value for a particular attribute. Let the set  $A = \{a_1, a_2, \dots, a_{|A|}\}$  denote the attributes,  $AC$  the set of true/false conditions on  $a_i$  ( $i = 1, \dots, |A|$ ), and  $ac_p$  be the true/false value of attribute  $a_i$  for a patient  $p$ . The set of treatment recommendations is denoted as  $T = \{t_1, t_2, \dots, t_{|T|}\}$  and the rule set is denoted as  $R = \{r_1, r_2, \dots, r_{|R|}\}$ . Each rule  $r_n$  ( $n = (1, \dots, |R|)$ ) is an implication of the form of  $x \rightarrow y$  where  $x \subseteq AC$  and  $y \in T$ . The dataset containing patient observations/profiles is denoted as  $O = \{O_1, O_2, \dots, O_{|O|}\}$ , where  $O_p = \{ac_{1p}, ac_{2p}, \dots, ac_{|A|p}\}$  denotes the set of observations of a particular patient  $p$  ( $p = (1, \dots, |O|)$ ). Given  $O_p$  and  $R$ , the system will form a set of treatment recommendations  $T_p$  for a patient  $p$  as follows:  $\forall t_i \in T$ , if  $\exists r_n = x \rightarrow y$  where  $x \subseteq O_p$  and  $y = t_i$  then  $T_p = T_p \cup t_i$ . Recommendations are not unique for each rule, as different patient profile/observations may provoke the same treatment recommendation. Each treatment recommendation  $t_i \in T$  was assigned a unique FC identifier ( $fc$ ).

### 3.3 Service Attributes Extraction

In order to bootstrap the services, a broad selection of diabetes related services was extracted from the Medicare Benefits Schedule (MBS) database. This list was narrowed down by domain experts to include any and all services relating to Diabetes Type 2. This process amounted to a list of 32 services. The set of services will be denoted as  $S = \{s_1, s_2, \dots, s_{32}\}$  and each service has nine characteristics associated with it, denoted as  $s_i c_j$  ( $i = (1, \dots, 32); j = (1, \dots, 9)$ ). The characteristics of each service in the context of SVNs, were extracted from the MBS listings and include: **(1) ServiceID**: a unique identifier provided by Medicare. The ID number contains information about the 'family' of services a particular service belongs to. The first and second digits typically identify category and subcategory, and the last digit uniquely identifies the service. For example  $s_1 c_1 = 701$ ,  $s_5 c_1 = 2517$ ,  $s_6 c_1 = 2518$ ,  $s_7 c_1 = 2521$ ,  $s_8 c_1 = 2522$  and  $s_{26} c_1 = 6651$ , all belong to the same 'family' (i.e. Consultations performed by General Practitioners in Vocational Register (REG-GP) and/or Fellow of the Royal Australian College (FRACGP)). They differ in terms of length (i.e. time needed to execute the service) and/or place (i.e. place of execution, usually defined as in or outside a facility). **(2) Description**: a short description for human interpretation, e.g.  $s_1 c_2 =$  "Brief Health Assessment",  $s_5 c_2 =$  'Consultation at consulting rooms' or  $s_{26} c_2 =$  'Quantitation of glycosylated haemoglobin'. **(3) Duration**: refers to the time needed to execute a service. Duration is expressed in a minute interval, e.g.  $s_5 c_3 = 0-20$ ;  $s_7 c_3 = 20-40$ ;  $s_9 c_3 > 40$ . **(4) Fee**: refers to the total amount in Australian dollars that will be charged for the service, e.g.  $s_5 c_4 = \$35.6$ ;  $s_{26} c_4 = \$16.9$ . **(5) Benefit%**: refers to the percentage of the fee that can be claimed for reimbursement, e.g.  $s_5 c_5 = 100\%$ ;  $s_{26} c_5 = 75\%$ . **(6) Benefit**: reflects the actual amount that can be claimed for reimbursement, e.g.  $s_5 c_6 = \$35.6$ ;  $s_{26} c_6 = \$12.7$ .

### 3.4 Business Rules Extraction

In the MBS schedule listings, business rules regarding the Medicare items are described in free text and as a result are not machine-readable. We started off by extracting the rules and formalising them using straightforward if-then logic. This resulted in three business rule types that double as service attributes (doubling as service attributes allows for an unambiguous mapping of rules to services in our framework): **(7) CustomerRule**: pertains to constraints for service delivery related to the status of the customer, e.g.  $s_1 c_7 =$  "IF diabetes established THEN use  $s_5$ ",  $s_8 c_7 =$  "IF number of patients  $> 7$  THEN  $s_8 c_4 = s_7 c_4 * (\text{number of patients} * 1.9)$ ". **(8) ProviderRule**: pertains to constraints for services of which the delivery can only be performed by service providers with a certain status, e.g.  $s_5 c_8 =$  "IF provider is REG-GP or FRACGP THEN valid ELSE use  $s_{11}$ ". **(9)**

**ServiceRule**: refers to rules regarding the relation of a service to other services, e.g. service items that are iterations of each other; that are identical services with a different length, service dependencies, etc. For example,  $s_{28C9}$  = “Valid if patient has been delivered  $s_{27}$ ” (in this case  $s_{27}$  is an assessment to be allowed to group service  $s_{28}$ ).

### 3.5 Examples of Business Rule Formalisation using SBVR

The type of language used in the business rules above does not allow for easy readability by business providers. In order for service providers to easily interpret and express applicable business rules, they are formalised in a standards-compliant near-natural language SBVR format, which consists of business rules and supporting fact types. Examples are given below. The legend for the notation is as follows: underline is a concept; double underline is an instance; bold is a **rule or constraint**; and cursive is a *relation*.

#### 3.5.1 Business Rule A5

**It is permitted that a** Medical Practitioner renders a Special Diabetes Attendance **if and only if** the Medical Practitioner is listed in Vocational Register of General Practitioners or the Medical Practitioner holds Fellowship of the Royal Australian College of General Practitioners

Supporting fact types for Rule A5:

Medical Practitioner renders Usual Attendance  
Diabetes Attendance specialises Attendance  
Special Diabetes Attendance specialises Diabetes Attendance  
Medical Practitioner is listed in Register  
Medical Practitioner holds Fellowship  
Vocational Register of General Practitioners is a Register  
Fellowship of the Royal Australian College of General Practitioners is a Fellowship

#### 3.5.2 Business Rule A44

**If a** Patient has been diagnosed with Diabetes Mellitus **and** has completed diabetes care cycle **then it is not permitted that the** Patient is given a Normal Attendance

Or the equivalent of the above negation:

**If a** Patient has been diagnosed with Diabetes Mellitus **and** has completed diabetes care cycle **then it is obligated that the** Patient is given a Diabetes Attendance

With supporting fact types:

Patient has been diagnosed with Diabetes Mellitus  
Diabetes Mellitus is a Disease  
Patient has completed diabetes care cycle  
Patient is given Attendance

We devise a category of attendances that is exclusive from the usual attendances treated in business rule A5.

Special Attendance specialises Attendance

**Exclusion between** Usual Attendance **and** Special Attendance:

**No** Usual Attendance is a Special Attendance

### 3.6 Business Rules Mapping

Once all services were itemized, they were mapped to the FCs under guidance of a domain expert. Mappings were non-exclusive, i.e. an FC can be satisfied with multiple services and a single service can satisfy multiple FCs. Hence, each FC was mapped to one or more services that it requires to produce the set of mappings  $M = \{m_1, m_2, \dots, m_{|M|}\}$ , where each  $m \in M$  is a 2-tuple denoted as  $(fc_i, ms)$ , where  $fc_i$  ( $i = (1, \dots, |T|)$ ) is a FC identifier and  $ms \subseteq S$ . Identical services of varying duration were assigned exclusive FCs within their family. For example,  $fc_2$  (“Measure blood pressure”) can be satisfied by the services  $s_5$  ( $s_{5C3} = 0-20$ );  $s_7$  ( $s_{7C3} = 20-40$ ); and  $s_9$  ( $s_{9C3} = >40$ ). A blood pressure measurement only takes short time, and if that is all that is needed it is performed by  $s_5$ . However, if patient requires one or more additional FCs at the same time,  $fc_2$  would be amalgamated into the service with longer duration (e.g.  $s_9$ ).

## 4. CASE STUDY AND EVALUATION

### 4.1 Experimental setup

*Customer perspective:* we ran 493 different patient profiles (i.e.  $|O| = 493$ ) through the patient rule base with 111 patient rules (i.e.  $|R| = 111$ ). Note that a single profile can trigger multiple rules resulting in multiple treatment recommendations or FC. From the 493 profiles, 1090 rules were triggered while 64 profiles did not trigger any rules (no treatment was required). Each FC was mapped to one or more services, i.e. the mapping  $M$  ( $|M| = 27$ ) was produced between 27 FCs ( $\{fc_1, \dots, fc_{27}\}$ ) (shown on the bottom right of Figure 2) and the 32 services ( $S = \{s_1, \dots, s_{32}\}$ ) (shown on the bottom left of Figure 2). Although all profiles were different, the requested FCs were often very similar (as can be expected in a context of standardized medical treatment). For this reason, we opted to select a sample of 5 very different profiles for the SVN composition for demonstration purposes.

*Service provider perspective:* we used 10 different service providers (denoted as  $SP_1, \dots, SP_{10}$ ) who between them had 45 single services (i.e. unique service-provider combinations). Each  $SP$  can provide multiple services as can be seen in the top right table of Figure 2 (where we show all services each  $SP$  provides). The total pool of service providers could satisfy all possible FCs.

*Service value networks:* The 5 profiles generated up to 20 alternative SVNs each. Although it is possible to generate more, the number was restricted for practical purposes. Out of our sample of 493 patient profiles, we selected a representative profile given by patient  $p=29$ . In the following section, we will elaborate on the process using this patient profile as an example.

### 4.2 Case Study: Patient Number 29

Patient Number 29 has established Type 2 diabetes and is already part of a cycle of care involving his condition. He has had prior advice to make lifestyle modifications, and has a heart condition. His blood pressure sensor indicates that his blood pressure has risen above a predefined threshold, which has triggered a number of rules, resulting in a set of required FCs:

#### 4.2.1 Patient Rules and Resulting Functional Consequences for Patient 29:

Running the sensor readings of Patient 29 through the rule base, three rules are activated as below:

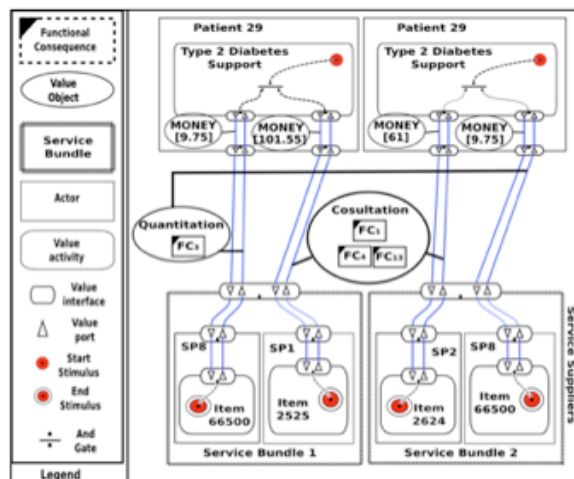
<p><i>Matched to Patient Rule 8</i>                      IF One of the following applied?                      Angiotensin converting enzyme inhibitors, angiotensin receptor blockers  calcium channel blockers, beta-blockers and diuretics=no AND BP &lt; 125/75 mmHg=no AND Proteinuria &gt; 1 g/day=yes AND Combinations of antihypertensive agents=no AND DiscussedLifeModificationFactors=yes                      THEN High blood pressure (it should be &lt; 125/75 mmHg): Initial therapy: (One of the following) angiotensin converting enzyme inhibitors  angiotensin receptor blockers, calcium channel blockers, beta-blockers and diuretics                      (maps to <math>fc_1</math> and <math>fc_3</math>)</p>	<p><i>Matched to Patient Rule 29</i>                      IF BP &lt; 125/75 mmHg=no                      Heart Failure=yes AND Proteinuria &gt; 1 g/day=yes AND Combinations of antihypertensive agents=no AND DiscussedLifeModificationFactors=yes                      AND Combinations of angiotensin converting enzyme inhibitors and/or diuretic and/or beta-blockers=yes                      THEN high blood pressure (it should be &lt; 125/75 mmHg): Combinations of antihypertensive agents                      (maps to <math>fc_4</math>)</p>	<p><i>Matched to Patient Rule 44</i>                      IF BP &lt; 125/75 mmHg=no AND Proteinuria &gt; 1 g/day=yes AND Combinations of antihypertensive agents=no AND DiscussedLifeModificationFactors=yes                      AND Intermittent Claudication=yes THEN high blood pressure (it should be &lt; 125/75 mmHg): Consider combinations of antihypertensive agents, avoid beta-blockers.                      (maps to <math>fc_{13}</math>)</p>
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The rules have triggered a treatment recommendation  $T_{29} = \{fc_1, fc_3, fc_4, fc_{13}\}$  for patient  $p = 29$ . This serves as the input for the SVN composition process.

#### 4.2.2 Services and Triggered Business Rules:

The set of recommendations  $T_{29} = \{fc_1, fc_3, fc_4, fc_{13}\}$  are satisfied by services  $s_2$  ( $s_2c_1=703$ ),  $s_3$  ( $s_3c_1=705$ ),  $s_4$  ( $s_4c_1=707$ ),  $s_5$  ( $s_5c_1=2517$ ),  $s_7$  ( $s_7c_1=2521$ ),  $s_9$  ( $s_9c_1=2525$ ),  $s_{11}$  ( $s_{11}c_1=2620$ ),  $s_{12}$  ( $s_{12}c_1=2622$ ),  $s_{13}$  ( $s_{13}c_1=2624$ ),  $s_{20}$  ( $s_{20}c_1=66500$ ).





Service Provider	Services
SP1	s1, s2, 3, s4, s5, s6, s7, s8, s9, s10
SP2	s1, s2, 3, s4, s11, s12, s13, s14, s15, s16
SP3	s17, s27, s28
SP4	s17
SP5	s18, s29, s30
SP6	s20, s21, s22, s23, s24, s25, s26
SP7	s21
SP8	s11, s12, s13, s14, s15, s16
SP9	s19, s31, s32
SP10	s19

Service	ServiceID	Description
1	701	Brief Health Assessment
2	703	Standard Health Assessment
3	705	Long Health Assessment
4	707	Prolonged Health Assessment
5	2517	Consultation at consulting rooms
6	2518	Consultation at a place other than consulting rooms
7	2521	Consultation at consulting rooms
8	2522	Consultation at a place other than consulting rooms
9	2525	Consultation at consulting rooms
10	2526	Consultation at a place other than consulting rooms
11	2620	Standard/surgery consultation
12	2622	Long/surgery consultation
13	2624	Prolonged/surgery consultation
14	2631	Standard/out-of-surgery consultation
15	2633	Long/out-of-surgery consultation
16	2635	Prolonged/out-of-surgery consultation
17	10951	Diabetes education service
18	10953	Exercise physiology
19	10954	Dietetics service
20	66500	Quantitation in serum, plasma, urine or other body fluid
21	66503	2 x 66500
22	66506	3 x 66500
23	66509	4 x 66500
24	66512	5 x 66500
25	66536	Quantitation of HDL cholesterol
26	66551	Quantitation of glycosylated haemoglobin
27	81100	Diabetes education service - assessment for group services
28	81105	Diabetes education service - group service
29	81110	Exercise physiology - assessment for group services
30	81115	Exercise physiology - group service
31	81120	Dietetics service - assessment for group services
32	81125	Dietetics service - group service

FC	Description
FC0	no action
FC1	Measure blood pressure
FC2	Lifestyle modifications
FC3	Initial therapy: (One of the following) angiotensin converting enzyme inhibitors, angiotensin receptor blockers, calcium channel blockers, β-blockers and diuretics
FC4	Consider combinations of antihypertensive agents
FC5	Initial therapy: consider combinations of angiotensin converting enzyme inhibitors and angiotensin receptor blockers.
FC6	Initial therapy: diuretics.
FC7	Consider combinations of antihypertensive agents and angiotensin receptor blockers
FC8	Initial therapy: consider combinations of angiotensin converting enzyme inhibitors and/or β-blockers.
FC9	Initial therapy: consider combinations of angiotensin converting enzyme inhibitors and/or diuretic and/or β-blockers.
FC10	Initial therapy: β-blockers.
FC11	Initial therapy: calcium channel blockers or thiazide diuretic
FC12	Initial therapy: α-blockers.
FC13	Consider combinations of antihypertensive agents, avoid β-blockers.
FC14	Pharmacological options selected on the basis of individual clinical circumstances, side effects and contraindications: (a) metformin
FC15	Pharmacological options selected on the basis of individual clinical circumstances, side effects and contraindications: (b) sulphonylurea
FC16	Pharmacological options selected on the basis of individual clinical circumstances, side effects and contraindications: (c) add-on therapies: acarbose, DPP-4 inhibitors, exenatide
FC17	Pharmacological options selected on the basis of individual clinical circumstances, side effects and contraindications: (d) insulin: basal or premixed
FC18	No response to treatment after 3-6 months: intensify treatment
FC19	No response to treatment: assess the patient for other condition (Latent Autoimmune Diabetes of Adults [LADA], malignancy)
FC20	Combination of statin and a bile acid binding resin or low dose nicotinic acid
FC21	Specific dietary advice for weight reduction
FC22	Improve blood glucose control
FC23	No change after 3 months: lipid modifying medications
FC24	No change after 3 months: statin therapy
FC25	Combination of statin and fibrate
FC26	No change after 3 months: intensify statin therapy or consider fibrates
FC27	No change after 3 months: fibrates

Figure 2: Service Value Network, FCs, Services and Service Providers

These services initially trigger a number of business rules that are represented as follows:

**Business Rule A5** (triggered by 2517, 2521, and 2525): **It is permitted that a Medical Practitioner renders 2517 if and only if the Medical Practitioner is listed in Vocational Register of General Practitioners or the Medical Practitioner holds Fellowship of the Royal Australian College of General Practitioners**

Supporting fact types:

2517 is a Special Diabetes Attendance  
2620 is a Diabetes Attendance



*Business Rule A44* (triggered by 701-707, 2517-2526, and 2620-2635): *If a Patient has been diagnosed with Diabetes Mellitus and has completed diabetes care cycle then it is obligated that the Patient is given a Diabetes Attendance*

Instances for Diabetes Attendance are 2517, 2518, 2521, 2522, 2525, 2526, and 2620, 2622, 2624, 2631, 2633, 2635. If we look at the case of Patient 29, we can see that our patient has already been diagnosed with Diabetes. This excludes services 701, 703, 705, and 707 from the possible SVNs.

#### 4.2.3 SVN Composition

After applying the business rules, the applicable mappings from the predefined set  $M$  are  $(fc_1, \{s_5, s_{11}\}) \subseteq m_1$ ,  $(fc_3, \{s_7, s_{12}, s_{20}\}) \subseteq m_3$ ,  $m_4 = (fc_4, \{s_9, s_{13}\}) \subseteq m_4$ ,  $(fc_{13}, \{s_9, s_{13}\}) \subseteq m_{13}$ .  $s_5, s_7$  and  $s_9$  are all consultations by REG-GP or FRACGP, and are amalgamated to  $s_9$ .  $s_{11}, s_{12}$  and  $s_{13}$  are consultations performed by other medical practitioners, and are amalgamated to  $s_{13}$ .  $s_{20}$  is a quantification service. The end result of the amalgamation is that  $fc_1, fc_3, fc_4, fc_{13}$  are all amalgamated into  $s_9$  and  $s_{13}$ , and  $fc_{13}$  to  $s_{20}$ , resulting in three services overall. In the service provider pool,  $s_9$  is offered by  $SP_1, s_{13}$  by  $SP_2$  and  $s_{20}$  is only provided by  $SP_8$ . This results in two possible service bundles, as depicted in Figure 2. *Service bundle 1* is offered by a combination of  $SP_1$  and  $SP_8$  and has a total price of \$111.3. *Service bundle 2* is offered by a combination of  $SP_2$  and  $SP_8$  and has a total price of \$70.75. The difference between both bundles is that *Service bundle 1* has a higher quality of service as REG-GP and FRACGP are general practitioners who have additional qualifications. Depending on the preference and budget of the patient, *Service bundle 1* or *Service bundle 2* can be chosen.

## 5. DISCUSSION AND FUTURE WORK

Type 2 Diabetes Management uses a number of biological parameters related to blood pressure control, lipid control and blood glucose control. We currently only use blood pressure and blood glucose control in our framework as lipids cannot currently be measured via remote sensors. Although the rules are present in the rule base on the patient side, they are not taken into consideration for the SVN composition. This points to a future direction in the work that would involve a second cycle in the SVN composition process, where a functional consequence would be to measure lipids in the patient before suggesting other services. This would improve the accuracy and validity of the framework in the context of diabetes. We are currently also working with partial data on both sides of the equation. Patient data such as location would become relevant in other application domains such as for example in palliative care (e.g. when a patient falls on the floor and cannot stand up). Patient budget is also currently not taken into account: several price options are given, but no pre-selection is made based on the patient budget. On the provider side, the business rules currently only contain those rules pertaining to the application of the Medicare services as defined in the listings. This results in an incomplete representation of the real-world business context. For example opening hours, the number of patients who can be treated simultaneously, preferred network partners, etc. would add to the completeness and accuracy of the SVN composition. We would also like to extend the notion of service providers in the framework beyond professional service providers to for example friends and relatives (e.g. in the context of palliative care). Finally, *ServiceRules* are currently applied manually in the e3value SVN framework, resulting in an avoidable gap in the automation approach. We intend to extend e3value so that it can handle all business rules in an automated manner.

It should be noted that our framework offers an initial and rudimentary basis for the creation of value propositions for automated health service selection and composition based on biological parameters of the patient. As such, the framework constitutes research into *some* of the issues pertaining to health service delivery by a diverse health service provider network in a home care context. It provides value propositions for accurately matched services that are ultimately delivered by medical practitioners to patients in a social context.

## 6. CONCLUSION

We have demonstrated that our approach solves some of the technical challenges of the ambient assisted living domain and contributes to service value network composition. By integrating the ‘medical practice’ side of healthcare with the ‘business’ side of it through the application of SVN, we offer solutions to AAL Challenge 7: ‘Integration’. By using existing and available medical data, and by formalising the business rules using ‘business-friendly’ SBVR, we essentially open up the playing field for service providers, offering solutions to problems pertaining to AAL Challenge 3: ‘Heterogeneity’. By extracting and formalising rules and characteristics from the NHMRC guidelines and MBS listings, we offer solutions to the problems posed by AAL Challenge 4: ‘Formalisation’. The degree of automation, formalisation and integration currently provided by our framework makes a compelling case for the use of sensor-driven, automated service selection and composition in solving the future healthcare challenges of our ageing population.

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