Enhancing Guideline-based decision support with distributed computation through local mobile application

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About the MobiGuide Project Consortium

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- **UNIVERSITA DEGLI STUDI DI PAVIA** (UNIPV), Italy
- **UNIVERSITEIT TWENTE** (UT), Netherlands
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- **MOBIHEALTH BV** (MHBV), Netherlands
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- **BEACON TECH LTD** (BTL), Israel
- **ZorgGemak BV (**ZORG), Netherlands
- **ASSOCIACIO DE DIABETICS DE CATALUNYA** (ADC), Spain

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MobiGuide Overview (1)

What do patients and their care providers (CP) want?

- Patients go on with their daily life while being safe
  - Mobile monitoring devices  (BAN) and decision-support (DSS) can identify states that require attention
  - DSS is proactive and interactive
- DSS based on current evidence-based clinical GLs
  - System learns compliance and outcomes and can suggest modifications for evolving clinical guidelines
- System is secure & available any time, everywhere
  - DSS distributed: main DSS Server + light mobile DSS

MobiGuide Overview (2)

- Automatic decision support is specific to patient data
- Integrated PHR, accessible by CPs & patients
- Decision-support suited to patient's current personal context and changes in technological context
  - What are these contexts? Which are relevant to GLs? Activate predefined guideline plans per relevant context
- Shared decision-making- patients more involved

- **Mobi-Guide**

Continuous guidance for mobile patients **Clinical-guideline guidance**

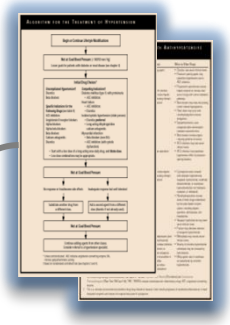
Overview general Architecture - Guideline-based DSSs : any time everywhere

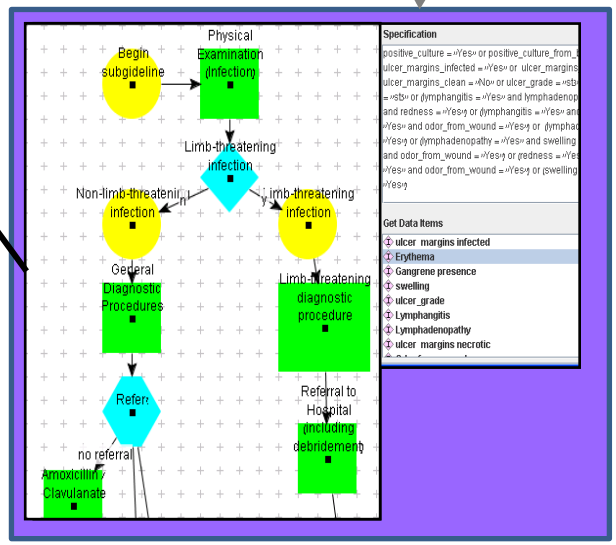



BAN

DSS

Personalized





EMR1

EMR2

PHR

Knowledge base of Computer-interpretable guidelines (CIG)

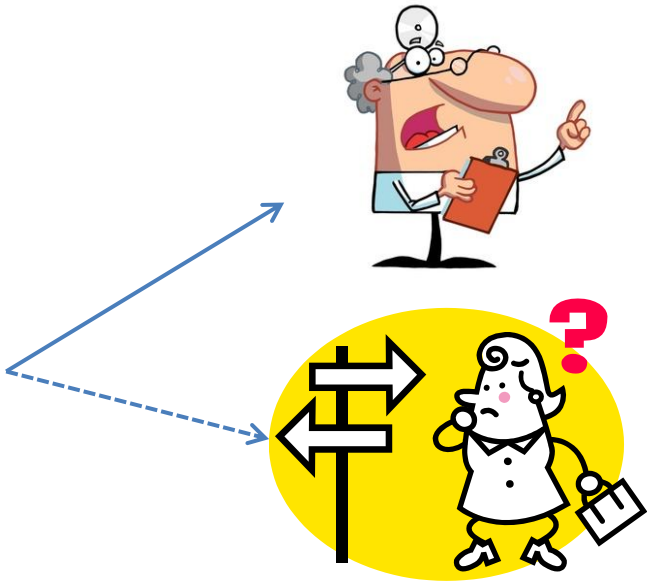
Decision-support distribution

“Traditional” Guideline-based decision support

RECOMMENDATIONS

CLASS I

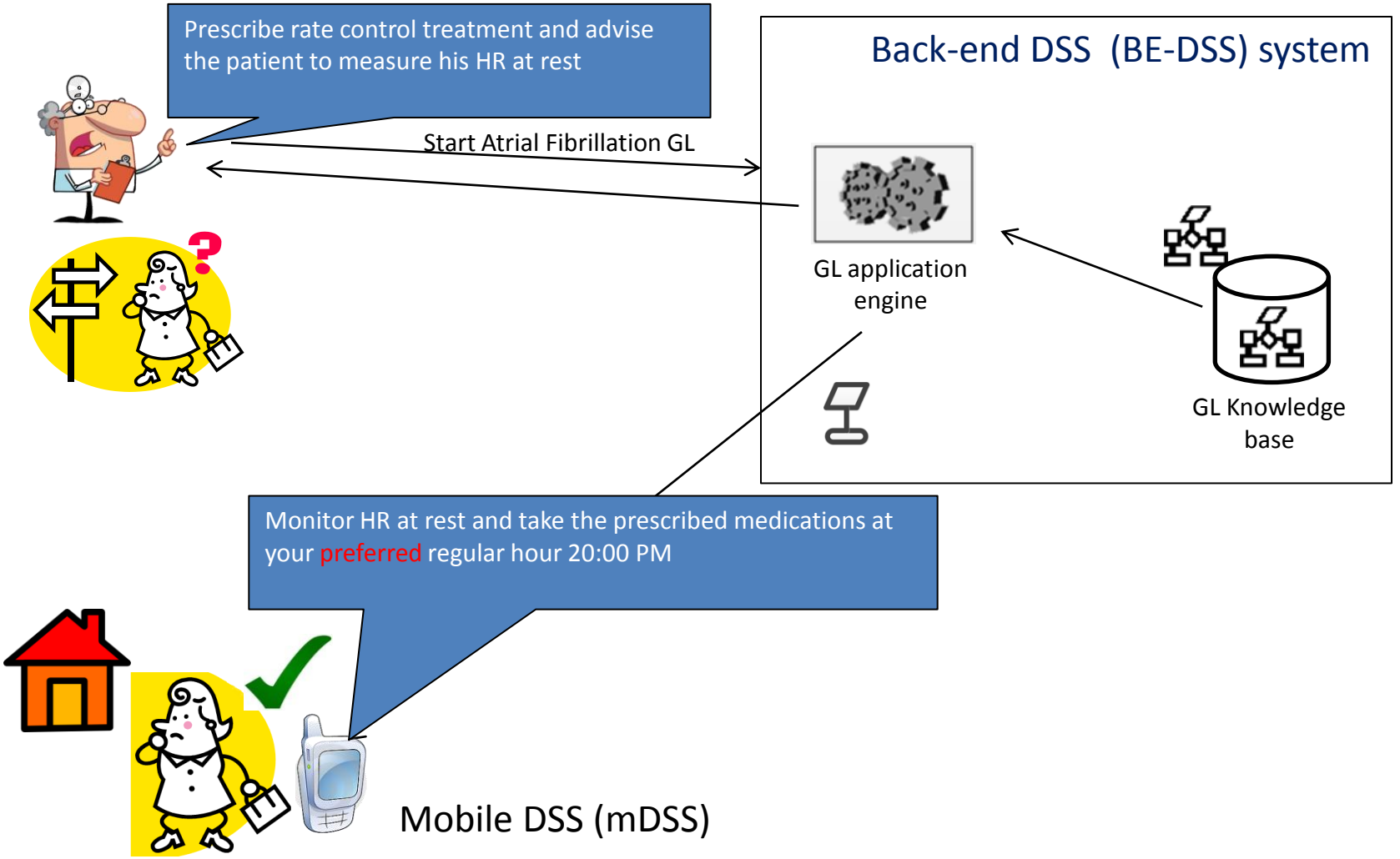
1. **Antithrombotic therapy to prevent thromboembolism is recommended for all patients with AF, except those with lone AF or contraindications.** ***(Level of Evidence: A)***
2. **The selection of the antithrombotic agent should be based upon the absolute risks of stroke and bleeding and the relative risk and benefit for a given patient.** ***(Level of Evidence: A)***
3. **For patients without mechanical heart valves at high risk of stroke, chronic oral anticoagulant therapy with a vitamin K antagonist is recommended in a dose adjusted to achieve the target intensity INR of 2.0 to**



- GLs Mostly address the physicians
- GLs do not address to the patient context and behaviour

Guideline-based Distributed decision support

"Measurement of the heart rate at rest and control of the rate using pharmacological agents ….are recommended for patients with persistent or permanent AF"



Levels of distributed decision support

- BE-DSS
  - Computational efficiency through distribution
  - Robustness to connectivity problems

- mDSS
  - solves the problem of over-burdaining the central server computationally.
  - Enable robust to problems in connectivity -
    The patient might be offline skiing in the Alps and still
    Getting recommendations !

The factors for decision-support distribution (I)

	Description		Examples	
	mDSS	BE-DSS	mDSS	BE-DSS
Computation	Intensive computation of short-term patterns	Complex patterns that require longitudinal data and additional knowledge	1 minute of 256Hz heart beats (irregular/regular)	3 repeating episodes of AF in past two months
Knowledge	Partial declarative and procedural knowledge	Full access to all knowledge during GL application session	Monitor 2 positive ketonuria values in a week	• Monthly BG good compliance
Data required or available	Recent, short-term data. Depend on mobile memory and GL needed	•Historical, long-term data of the full patient record, or even multiple patients	a week of ketonuria	GDM during previous pregnancies

The factors for decision-support distribution (II) - knowledge

Factor	mDSS	BE-DSS
Subject of Data	Data of patient only	When DSS needs population data (e.g., the average BG counts at a clinic) Data of all patients is needed
Data sources	Decision relies only on data entered from local sensors or entered manually by patients	Decision relies on data from different sources such as EMR data containing laboratory tests, medication prescriptions, and diagnoses
PHR access	Rather limited access the PHR to retrieve additional data, or to retrieve special types of data such as previous abstractions and recommendations	Can access the PHR to query for any type of EMR data, monitored data, previous abstractions of the data, and previous recommendations

The factors for decision-support distribution (III) - DATA

Factor	mDSS	BE-DSS
Actions	Actions are translated by the mDSS as an order to the Smartphone GUI	Actions are activated at the back-end server and sent to the mDSS at the patient's device
Personalization	invoke the personalized recommendations which are sent to the patient (e.g., with personal times for reminders)	Initially generates recommendation from the GL, and then makes them personalized by elaborate them with user preferences from the PHR, if there are any.
Quality of data	Decisions can be taken by referring to the QoD broker which Calculates the quality of data and saves results in PHR	Relies on the data that was saved on the PHR, thus enabling also the BE-DSS to consider QoD as part of the technological context in decision-making

Needs distribution policy

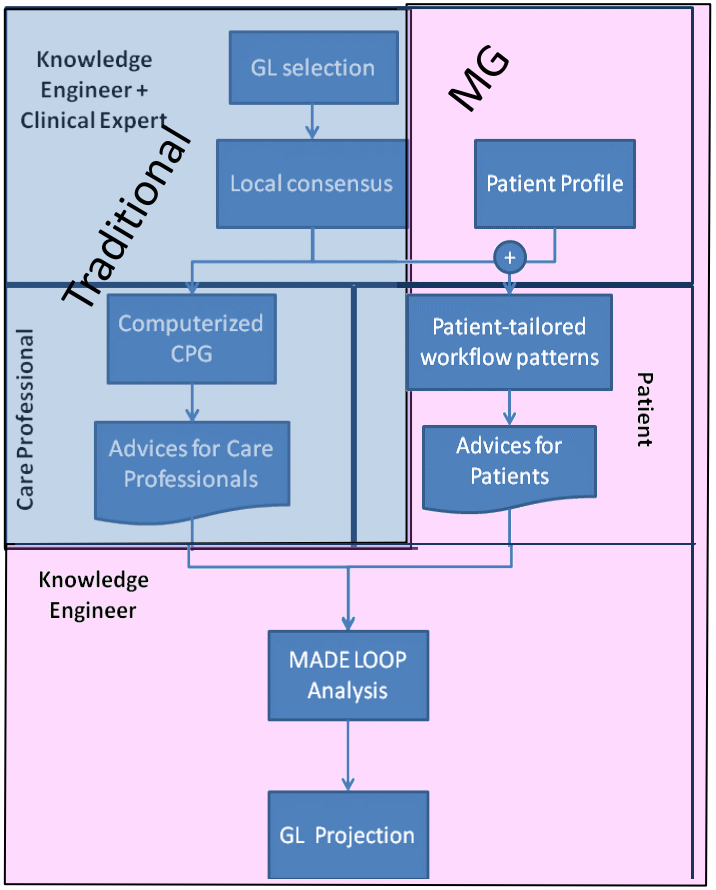
The distribution policy

Distribution policy	Description
Full mDSS	GL is projected completely to the mDSS and run exclusively by the mDSS
“Full shadow”	BE-DSS completely monitors mDSS actions
“Passing of control”	mDSS/ BE-DSS alternately switch control
Full BE-DSS	run exclusively by the BE-DSS

The knowledge projection model methodology

Distribution decision support methodology for GL elicitation

- Enhancing the GL with patient-centric parallel process (workflow)[Sacchi,2013]



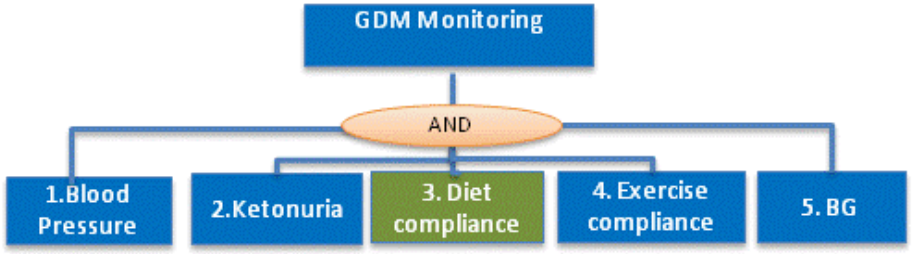
1. Sacchi L, Fux A, Napolitano C, Panzarasa S, Peleg M, Quaglini S, Shalom E, Soffer P, Tormene P. Patient-tailored Workflow Patterns from Clinical Practice Guidelines Recommendations. Journal Stud Health Technol Inform. 2013;192:392-6.

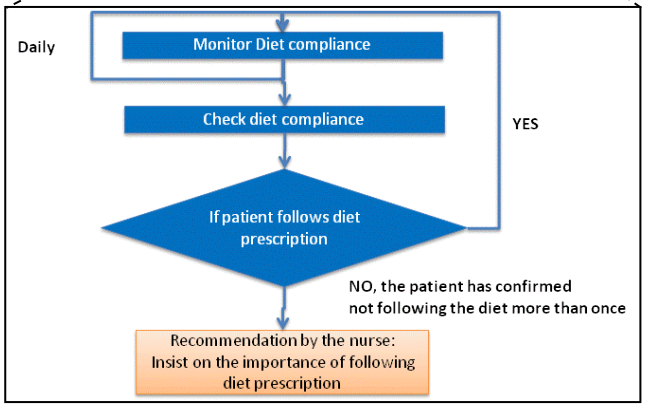
An example : Splitting the GL into Projection points

1. GL text :

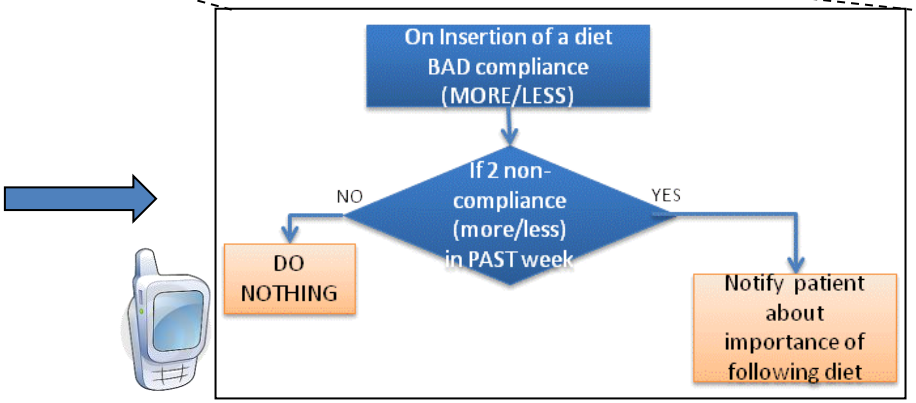
"If the patient was NOT COMPLIANT with the prescribed diet, the nurse should advise the patient on the importance of eating enough carbohydrates….." (the GDM GL)

2. GL consensus

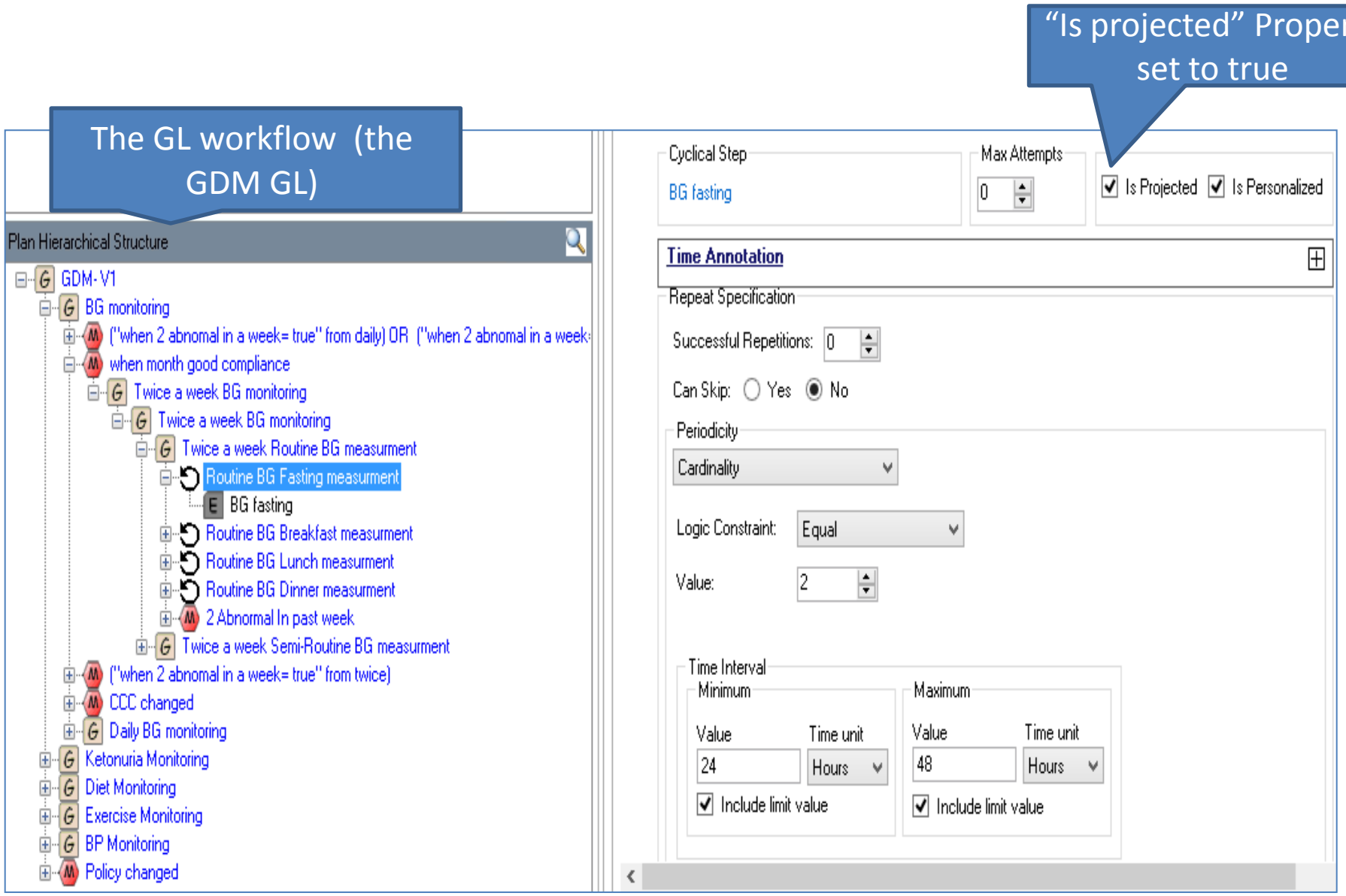




3. Projection point

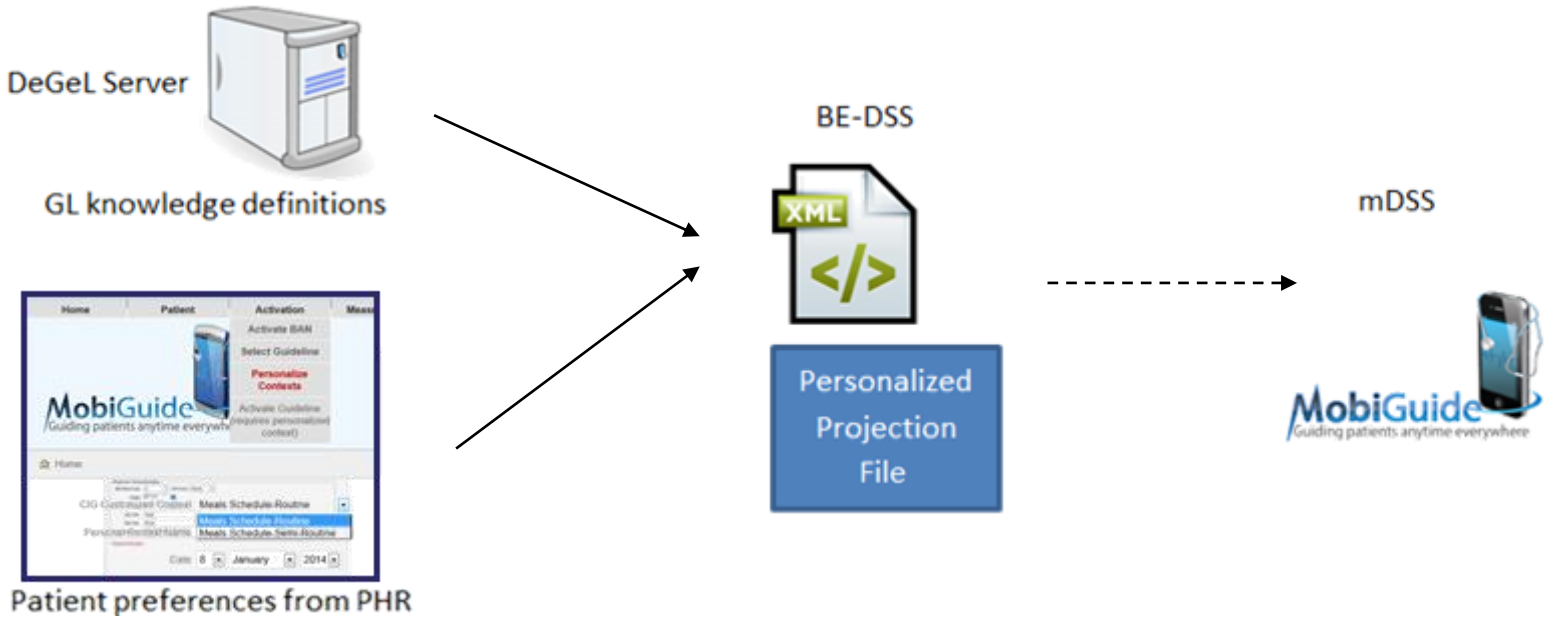


An example : Defining projection point using The GESHER GL Knowledge Equitation Tool

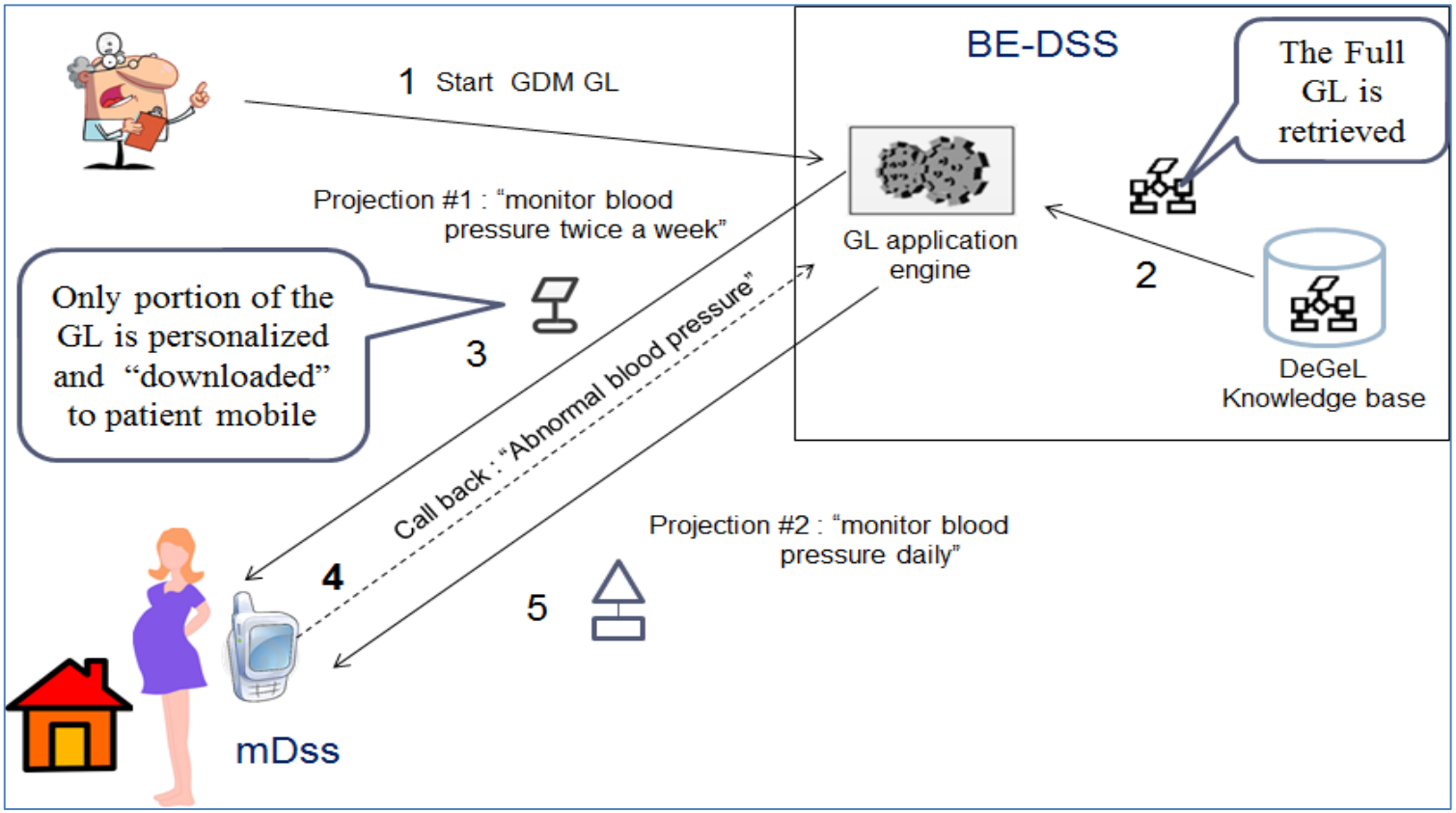


The Projection wrokflow

- The BE-DSS projects ("pushes") to the **mDSS** small portions of the GL, referred to as "**projections"**
- **A specific part of the GL** specialized to the **current context of the patient is projected**
- The projected knowledge also includes implicitly the **patient's preferences**



The projection workflow



The projection model implementation

The projection model main principles

- *Separation of declarative and procedural knowledge*
- *Support of Personalization*
- *Definition of appropriate callbacks*

Separation of declarative and procedural knowledge

- Each projection is one XML file
- Two types of knowledge:
  - *Declarative knowledge* projection
    - Needed for initiating the GUI and mDSS components BEFORE GL started
    - KB concepts (e.g. “BG Fasting”) to be mapped
    - Personal context (e.g. “Holiday”)
  - *Procedural knowledge* projection
    - Taking in account the current patient context
    - Set with patient preferences (e.g., alert at preferred hour)
    - Procedural directives (e.g. monitoring plans, repeating plans)

An example - declarative knowledge projection

```
<Projection GLID="19857" GLName="GDM">
    <QualityOfData>
        <QualityOfDataItem id="5560" description="Low" relateTo="4985,4986,4987,4988"/>
        <QualityOfDataItem id="5560" description="Very Low" relateTo="4985,4986,4987,4988"/>
        <QualityOfDataItem id="5559" description="Low" relateTo="5177,5178"/>
        <QualityOfDataItem id="5559" description="Very Low" relateTo="5177,5178"/>
    </QualityOfData>
    <personalEvents>
        <PersonalEvent ConceptID="5128" personalEvent="work">
            <Reminders>
                <Reminder Value="07:00" RemindTime="-5.0" GesherId="4985" Unit="minutes"/>
                <Reminder Value="08:00" RemindTime="-5.0" GesherId="4986" Unit="minutes"/>
                <Reminder Value="12:30" RemindTime="-5.0" GesherId="4987" Unit="minutes"/>
                <Reminder Value="20:00" RemindTime="-5.0" GesherId="4988" Unit="minutes"/>
            </Reminders>
        </PersonalEvent>
        <PersonalEvent ConceptID="5129" personalEvent="holiday">
            <Reminders>
                <Reminder Value="07:00" RemindTime="-5.0" GesherId="4985" Unit="minutes"/>
                <Reminder Value="09:00" RemindTime="-5.0" GesherId="4986" Unit="minutes"/>
                <Reminder Value="13:30" RemindTime="-5.0" GesherId="4987" Unit="minutes"/>
                <Reminder Value="21:00" RemindTime="-5.0" GesherId="4988" Unit="minutes"/>
            </Reminders>
        </PersonalEvent>
    </personalEvents>
</Projection>
```

Quality of data thresholds

Personal events

An example: unit-projections in the case of GDM GL

- Each projection-point is translated to unit-projection

Plan	Unit-Projection Name	Unit-Projection ID
Blood glucose	**Measure** Routine BG daily Fasting measurement	20091
	Monitor 2 abnormal measurement in past week (call back from Daily)	20095
Ketonuria	**Measure** katenuria daily	19964
	Monitor 2 positive in one week (call back from daily)	19965
Diet	**Measure** Weekly diet non compliance	20133
Exercise	**Measure** Weekly METS	20010
Normal blood pressure	**Measure** BP twice a week **Measure** BP once a week (once a week)	20026 20047
Chronic blood pressure	**Measure** every 2 days with Target-organ damage	20140
	Monitor sBP >= 140 and/or dBP >= 90*	20144
Gestational Blood pressure	**Measure** BP every 2 days, 1 measure per day	20164
	Monitor sBP ≤ 149 OR dBP ≤ 99	20168

An example - procedural knowledge projection

Stop/start list

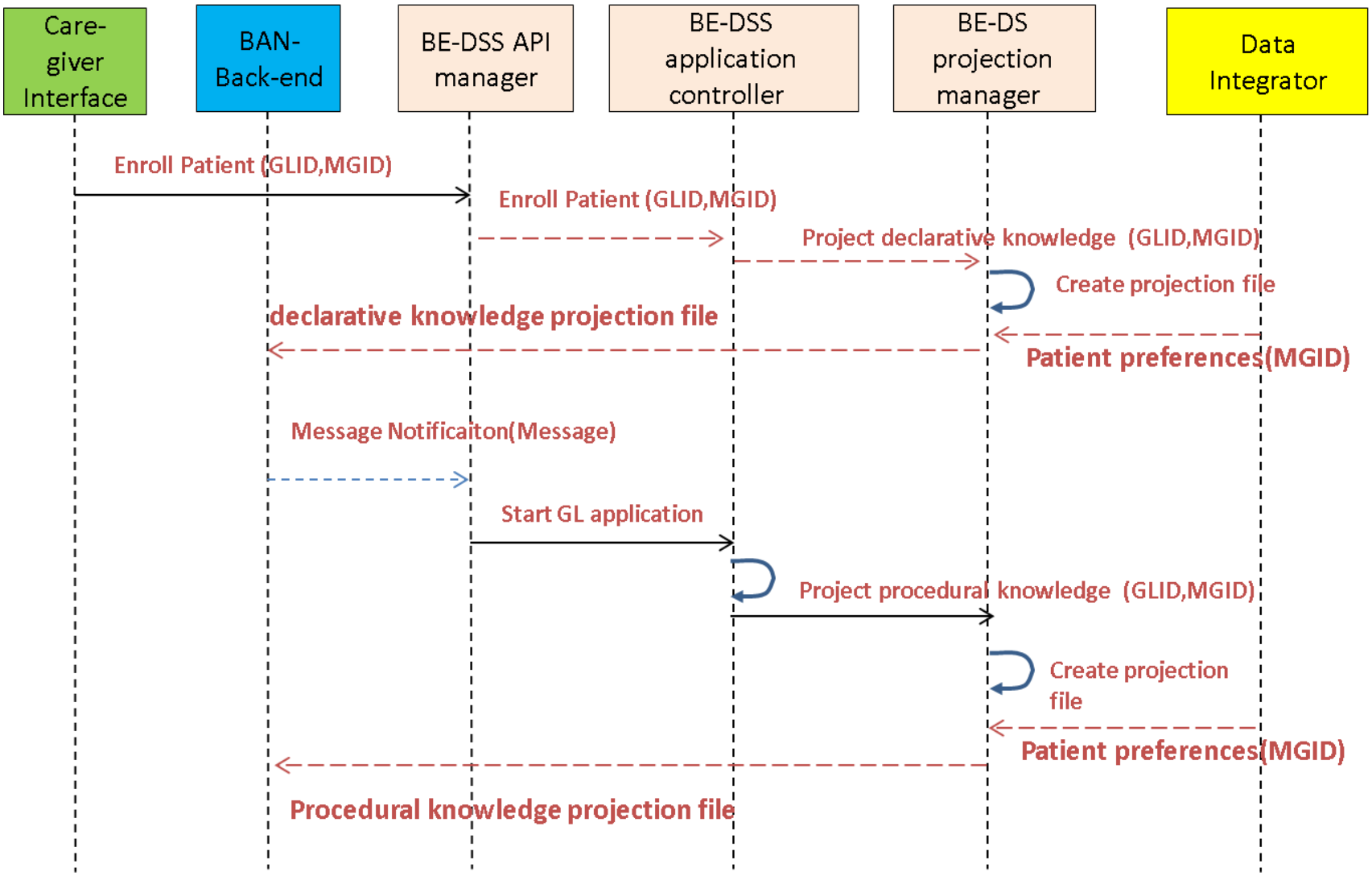
Personalized scheduling

Blood glucose Measurement plan

Monitoring plan

```
projection("19857", id="184");

stop("20091,20092");

start("20102,20130");


unitProjection("20102","Semi-Routine Daily  Fasting measurement") {

        while (true) {
                waitPeriodic("1,2,3,4,5,6,7", "8:00", null);
                event = createEvent();
                event.patientDataEntry("4985","BG Fasting","numeric","1 hour");
                event.insert();
        }
}


unitProjection("20130","2 abnormal measurements in past week") {

        annotateTemporal("or",new String[] {
                        "event.getNumber(4985)>=150",
                        "event.getNumber(4986)>=150",
                        "event.getNumber(4987)>=150",
                        "event.getNumber(4988)>=150"
                }, "abnormal_BG", "date" );

        while (true) {
                waitTemporalQuery("count >= 2", "abnormal_BG", "8 calendardays");
                callback("5112", "2 abnormal values in BG were found in your
                        measurements in the past week,
                        system is calculating another schedule for you for daily BG measurement");
        }
}
```

The projection workflow sequence diagram



Support of personalization

- An example: Monitoring BG trechoholds

```
unitProjection("20106","2 abnormal measurements in past week") {

        annotateTemporal("or",new String[] {
                        "event.getNumber(4985)>=<4985>",    "event.getNumber(4985)>=150",
                        "event.getNumber(4986)>=<4986>",    "event.getNumber(4986)>=150",
                        "event.getNumber(4987)>=<4987>",    "event.getNumber(4987)>=150",
                        "event.getNumber(4988)>=<4988>"     "event.getNumber(4988)>=150"
                }, "abnormal_BG", "date" );

        while (true) {
                waitTemporalQuery("count    2", "abnormal_BG", "8 calendardays")
                callback("5111", "2 ab    al values in BG were found in your    surements
                in the past week, sys    is calculating another schedule for    u");
        }
```

Knowledge thresholds are variables in design time

Set with personal threshold in runtime

Defining Appropriate call-backs

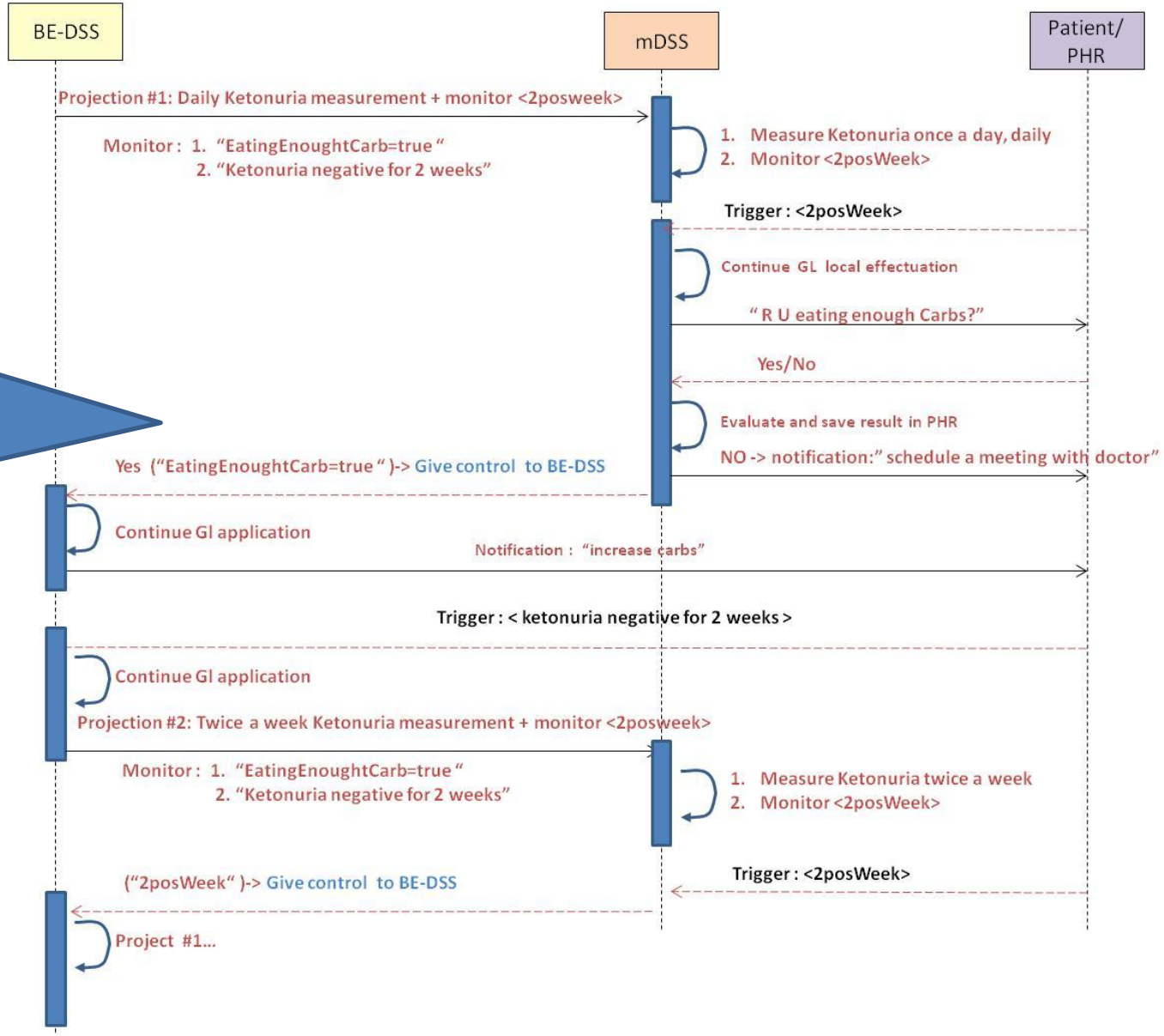
- predefined in the projection.
- Might lead to the sending of a new projection to the mobile.
- The projections and callbacks support a continuous dialog between the BE-DSS and the mDSS.
- In any case, the BE-DSS continues to apply the GL and to send the appropriate personalized projections to the mDSS when necessary.

```
unitProjection("20106","2 abnormal measurements in past week") {

        annotateTemporal("or",new String[] {
                        "event.getNumber(4985)>=<4985>",
                        "event.getNumber(4986)>=<4986>",
                        "event.getNumber(4987)>=<4987>",
                        "event.getNumber(4988)>=<4988>"
                }, "abnormal_BG", "date" );

        while (true) {
                waitTemporalQuery("count >= 2", "abnormal_BG", "8 calendardays");
                callback("5111", "2 abnormal values in BG were found in your measurements
                in the past week, system is calculating another schedule for you");
        }
```

Call back message

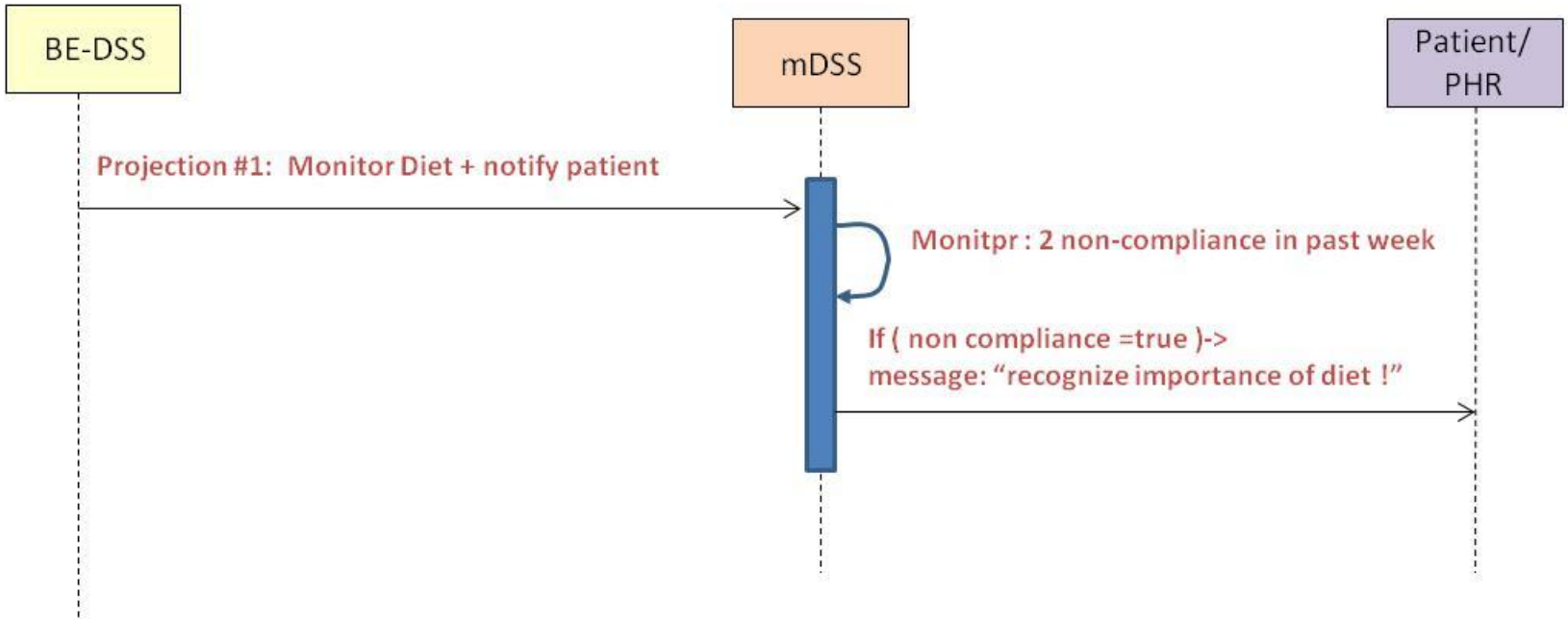
GDM Example1 : “ketonuria management”

“Call back” – Passing control between BE-DSS and mDSS



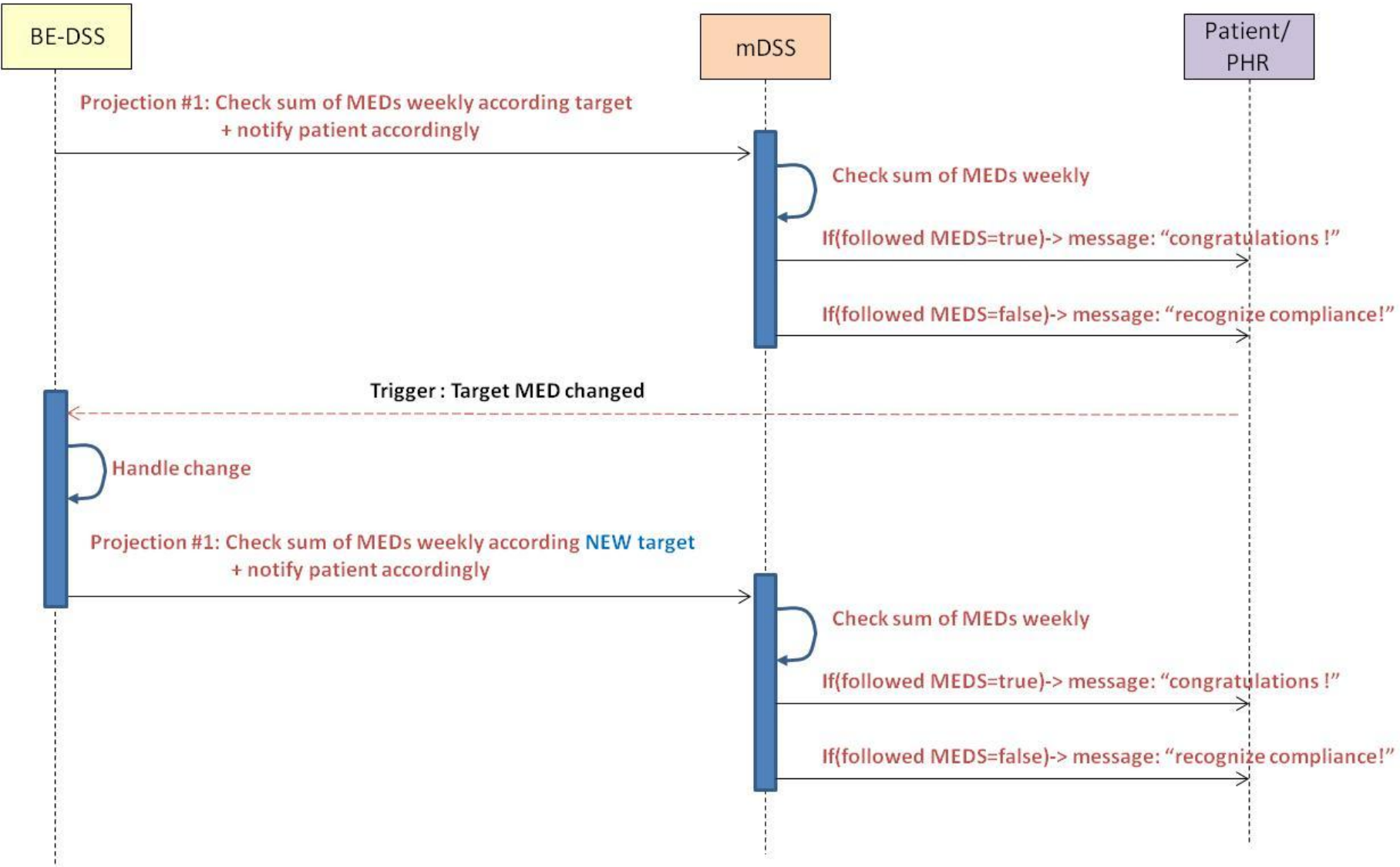
GDM Example 2 : Diet management

- Project once, monitor at mDSS constantly



GDM Example 3 : Exercise management

- Project when new target MED is changes



Summary and Discussion (I)

- Initially, the architecture included decision support (to both patients and clinicians) provided only by the BE-DSS.
- That, however, did not easily cater to multiple local monitoring actions and reminders or to the robustness of the system with respect to connectivity
- We added the projection and callback mechanisms, splitting the decision-support tasks between the BE-DSS and the mDSS
- The projection and callback mechanism that we are implementing supports a **continuous dialog** between the BE-DSS and the mDSS

Summary and Discussion (II)

- Currently, we are in year 3 of a 4-year project.
- In the case of the GDM guideline, 39 projection points were tagged, and in the case of the AF guideline, 20.
- Most of the projection points were cyclical plans for measurements (e.g. blood glucose), and callback messages which can significantly reduce the computational load on the BE–DSS.
- In the coming year, we will perform a pilot study
  - The GDM guideline in the case of the *Sabadell* Hospital in Barcelona, Spain,
  - The AF guideline in the case of the Fondazione Salvatore Maugeri , Pavia, Italy

Questions ?

Acknowledgments

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