Towards the Support of Design Patterns in the Fast Healthcare Interoperability Resources (FHIR) Standard

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Timoteus Ziminski, Short Biography

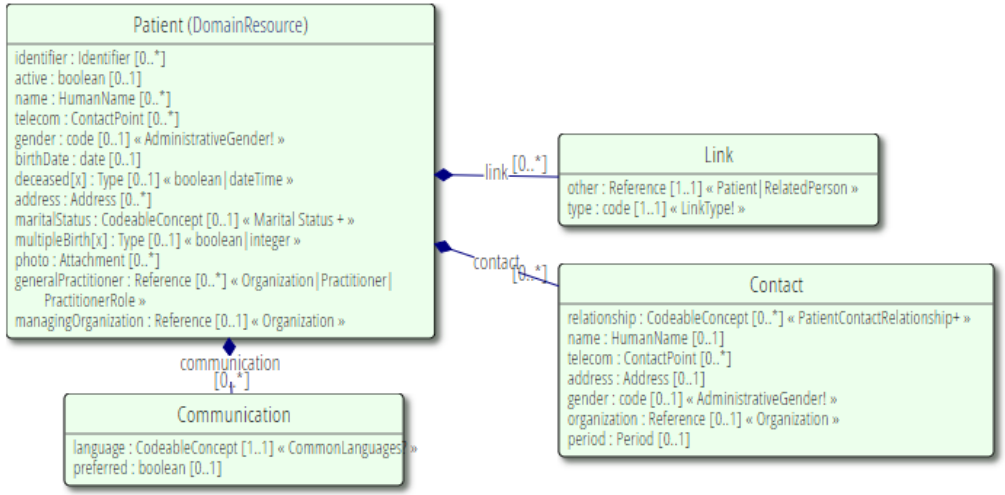
- PhD Student, Computer Science & Engineering, University of Connecticut
- Diplom-Informatiker (TU Dortmund University, 2009)
- Research interests:
  - Software architectures for Health Information Exchange
  - Applications in the biomedical and healthcare domain
  - Interoperability, data and system integration, and design methods
- Software engineer in the automotive industry (vehicle diagnostics with Java and Eclipse RCP)

FHIR and Health Information Exchange

- **FHIR:** successful HL7 INTL' standard to overcome interoperability issues
  - Passed through initial maturity level and currently widely endorsed (mandated by ONC)
- **Health Information Exchange:**
  - Vast domain with numerous stakeholders and systems
  - Demand and regulatory pressure to enable cross-institutional data sharing
  - Interoperability challenges

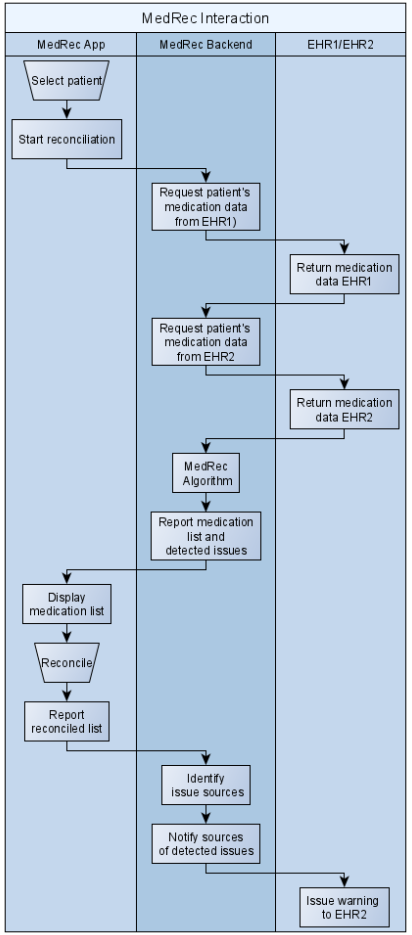
FHIR Features

- Over 135 resources to capture all types of healthcare data
  - *Base*: patients, practitioners,...
  - *Clinical*: patient's health history, diagnostic data,…
  - *Foundation*, *financial*, *specialized*…
- REST API for instance level interactions
- Open reference implementations (e.g., *HAPI FHIR*)



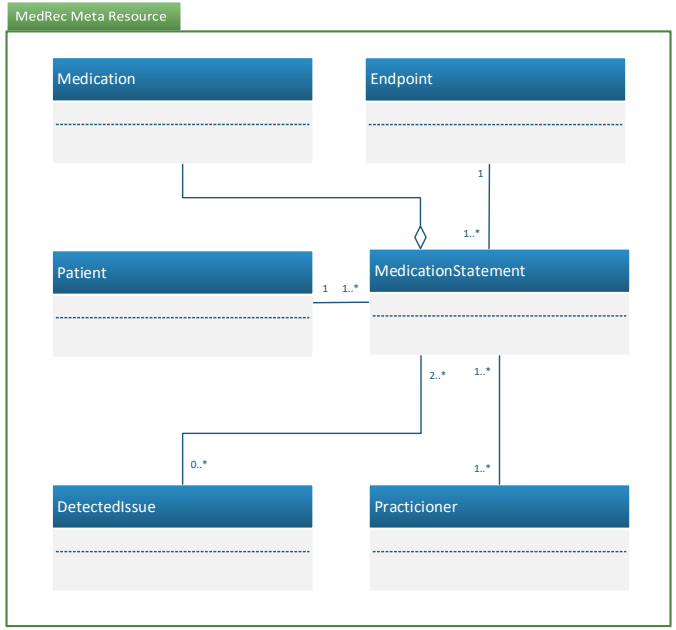
Medication Reconciliation

- **Medication reconciliation**
  - Compares a patient's medication orders to medications that the patient has been taking
  - Detect errors: omissions, duplications, dosing errors, interactions
  - Dangerous: Transition of care
- **MedRec application**
  - Requesting medication lists from multiple sources
  - Reconciliation by requests to RxNorm
  - Presentation of reconciled lists
  - Warnings for detected issues



Sample MedRec Meta Resource

- **MedRec uses FHIR resources**:
  - Patients, Practitioners, Medications, Medication Statements, Detected Issues, End Points
- **Observation:**
  - Likely same participating resources and relationships for each medication reconciliation system
- **What we propose:**
  - Reusable *meta resource*



Research Questions

- **Issue:** FHIR lacks a built-in way to organize a subset of resources for problem at design level
  - How to model a reusable artifact for functionality akin to a design pattern?
  - Which functionality needs to be provided by a design pattern-like extension?
- **Issue:** Integration of an extension into the FHIR framework
  - How can the provided extension be mapped to existing FHIR artifacts?
  - How can compatible artifacts be generated?

Meta Resource Model

- **Goal** Define a meta resource which
  - Is associated with a specific problem
  - Relates multiple FHIR resources
  - Provides information about the relationships of the included resources
  - Can be embedded in the existing FHIR framework
- **Approach**
  - Develop a formal view of FHIR resources to establish meta resource building blocks
  - Construction of meta resource from FHIR resources

FHIR Resource Example

- An FHIR Patient resource instance for patient John Doe after five changes is represented by
  - $R_1 =< R_{ID_1}, t_1, R_{Data_1}, x >$
    - $R_{ID_1} = http://test.fhir.org/rest/Patient/123$
    - $t_1 = Patient$
    - $R_{Data_1} = \{\{$"$identifier$" : "ea44426f",
      "$active$": "true",
      "name": "John Doe",
      "telecom": "555−370−8047",
      "gender": "male",
      "$birthDate$" : "1970 − 12 − 12",…}
    - $x = 5$

Meta Resource Model

- $MR = < MR_{ID}, MR_{Name}, MR_{Desc}, MR_{PR}, MR_{API}, MR_{REF}, MR_{COM} >$
- Meta resource model attributes:
  - *identifier*

    http://test.fhir.org/rest/meta/MedicationReconciliation/123
  - *name*

    MedicationReconciliation
  - *description*

    Medication reconciliation is the process of

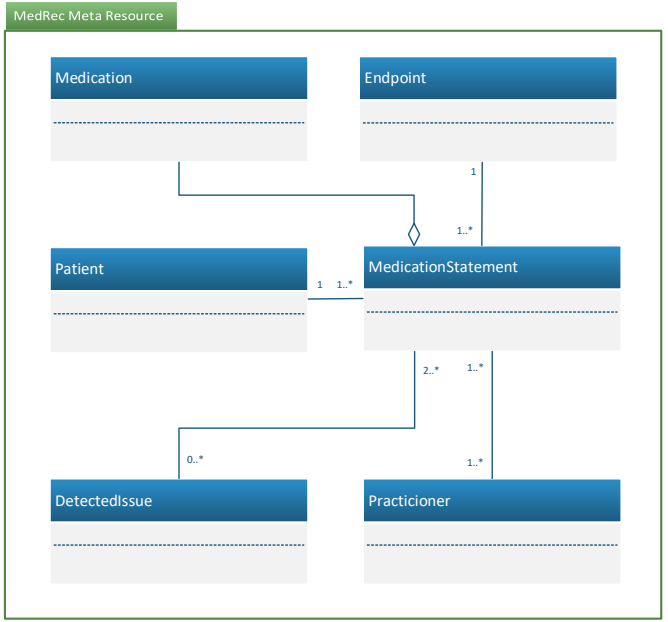
    comparing a patient's medication orders …
  - *participating resources*

    {<Patient,entity>, <MedicationStatement, producer>, …}
  - *reference structure*

    {<patient, medicationStatement>, <medicationStatement, endPoint>…}
  - *composition structure*

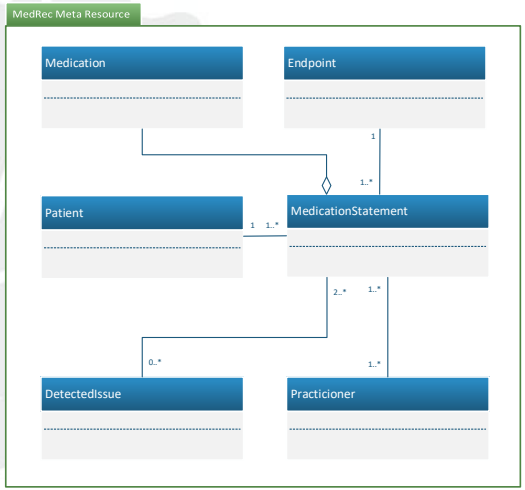
    {<medicationStatement, medication>}
  - *API extension*

    <FHIR profile>



FHIR Bundle Generation

- Source: Meta resource schema
- Target: FHIR Bundle schema

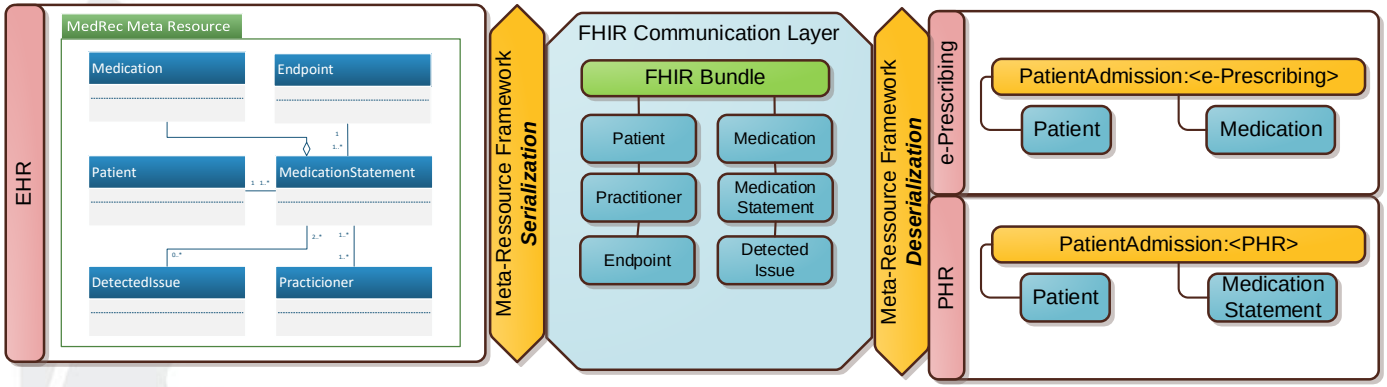



```
<Bundle xmlns="http://hl7.org/fhir">
<identifier><!-- 0..1 --></identifier>
 <type value="[code]"/><!-- 1..1 -->
 <timestamp value="[instant]"/><!-- 0..1 -->
 <total value="[unsignedInt]"/><!-- 0..1 -->
 <link>  <!-- 0..* -->
  <relation value="[string]"/>
    <!-- 1..1  -->
  <url value="[uri]"/><!-- 1..1 -->
 </link>
 <entry>  <!-- 0..* -->
  <link><!-- 0..* --></link>
  <fullUrl value="[uri]"/>
    <!-- 0..1 -->
  <resource><!-- 0.. --></resource>
  <search>  <!-- 0..1 ... --> </search>
  <request>  <!-- 0..1 ... -->
  <response>  <!--  0..1 ... --></outcome>
  </response>
 </entry>
 <signature><!-- 0..1 digital -->
</signature>
</Bundle>
```

FHIR Bundle Generation Result

```
<Bundle xmlns="http://hl7.org/fhir">
 <!-- for readability expand $url = http://hie.org/fhir -->
 <id value="bundle-metaressource-collection"/>
 <type value="collection"/>
 <entry>
  <fullUrl value="$url/Patient/123"/>
  <resource><Patient><!-- John Doe --></Patient></resource>
 </entry>
 <entry>
  <fullUrl value="$url/Practioner/123"/>
  <resource><Practitioner><!-- Dr. Max Mustermann --></Practitioner></resource>
 </entry>
 <!-- Further practioner entries -->
 <entry>
  <fullUrl value="$url/Endpoint/123"/>
  <resource><Endpoint><!-- hl7-fhir-rest endpoint --></Endpoint></resource>
 </entry>
 <!-- Further endpoint entries -->
 <entry>
  <fullUrl value="$url/MedicationStatement/123"/>
  <link><relation value="related"/><url value="$url/Patient/123"/></link>
  <link><relation value="related"/><url value="$url/Practioner/123"/></link>
  <link><relation value="related"/><url value="$url/Endpoint/123"/></link>
  <resource>
   <MedicationStatement>
    <id value="medstatemet001"/>
    <contained><Medication> <!-- id="med309" --></Medication></contained>
    <medicationReference><reference value="#med0309"/></medicationReference>
    <subject><reference value="Patient/123"/></subject>
   </MedicationStatement>
  </resource>
 </entry>
 <!-- Further MedicationStatement entries, including
 medstatement002 at $url/MedicationStatement/124 -->
 <entry>
  <fullUrl value="$url/DetectedIssue/123"/>
  <link><relation value="related"/><url value="$url/MedicationStatement/123"/></link>
  <link><relation value="related"/><url value="$url/MedicationStatement/124"/></link>
  <resource>
   <DetectedIssue>
    <code><!-- Drug Interaction Alert --></code>
    <implicated><reference value="MedicationStatement/medstatement001"/></implicated>
    <implicated><reference value="MedicationStatement/medstatement002"/></implicated>
   </DetectedIssue>
  </resource>
 </entry>
 <!-- Further DetectedIssue statements -->
</Bundle>
```

Meta Resource Integration



- EHR works based on the MedicationReconciliation meta resource
- PHR & e-Prescribing system are unaware of meta resources
- Bridging the gap through bundle generation
  - EHR serializes its meta resources to a bundle
  - PHR & e-Prescribing can extract their information from a standard FHIR Bundle

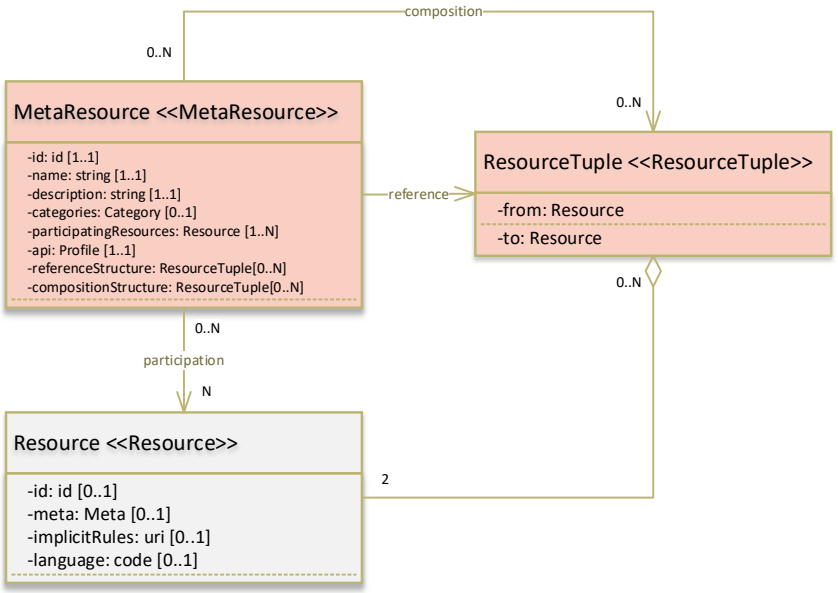
FHIR Facets

- Paths for integrating meta resources into FHIR standard specification
- *Facet 1*: FHIR resource extension
- *Facet 2*: DomainResource
- *Facet 3*: FHIR Modules
- *Facet 4*: Information architecture
- *Facet 5*: Library resources and ActivityDefinition resources

Facet 1: Meta Resources and FHIR Resources

- Schema level
  - Meta resource related to published FHIR resources
  - Higher-level artifacts that assemble participating resources enriched with context information
  - Design pattern-like concept
- Instance level
  - Meta resource instance group FHIR resource instances containing the relevant medical data
  - Share instances across FHIR systems
- Approach: Incorporating meta resources into FHIR by regarding them as entities related to FHIR resources

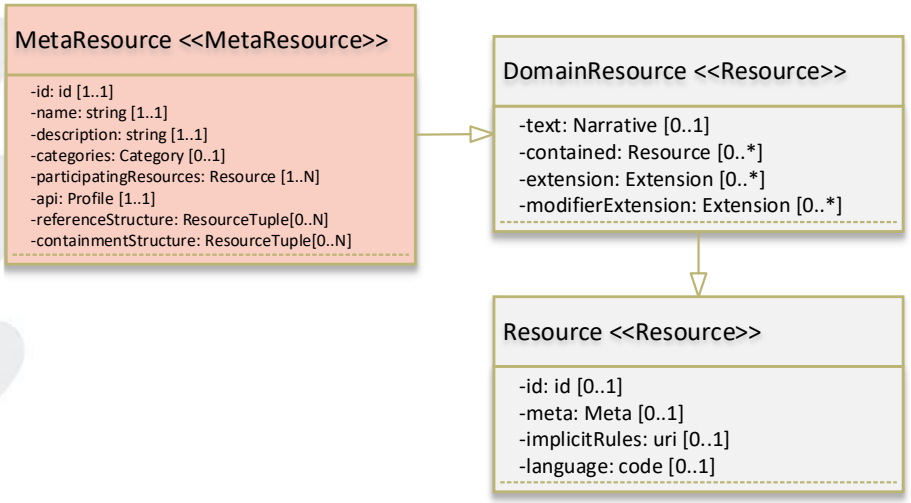
FHIR Resources Integration



Facet 2: DomainResource

- The FHIR DomainResource is an abstract foundation resource in the resource model
  - Provides functionality to derived resource (all except for Bundle, Parameter, and Binary)
- Provide *contained* property
  - Option to assemble other resources and serve as a container
  - Fundamentally useful for expressing participating resources
- Approach: Derive meta resource from DomainResource and employ *contained* property

DomainResource Integration



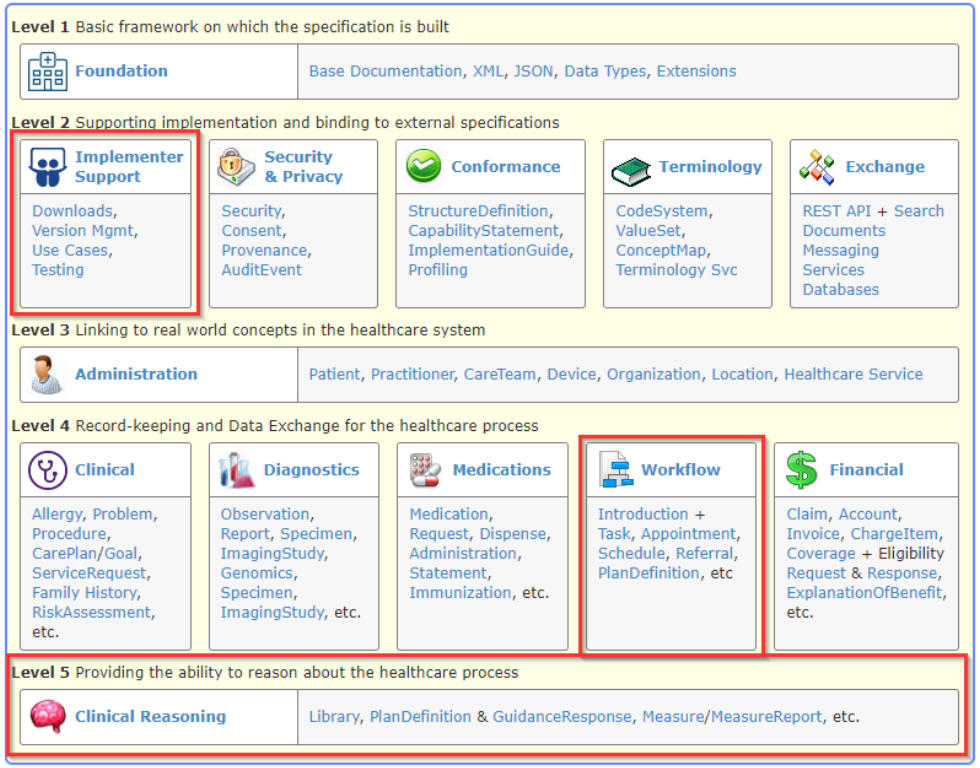
DomainResource Limitation

- Limitation:
  - Resources referenced by the *contained* property conceptually only exists in scope of container resource
  - Prohibits the goal of disassembling and partially using meta resources where they cannot be understood by plain FHIR systems
  - Composition and reference structures cannot be implemented without own identity of participating resources
- DomainResource functionality alone is not suitable to model meta resources within the FHIR standard

Facet 3: FHIR Modules

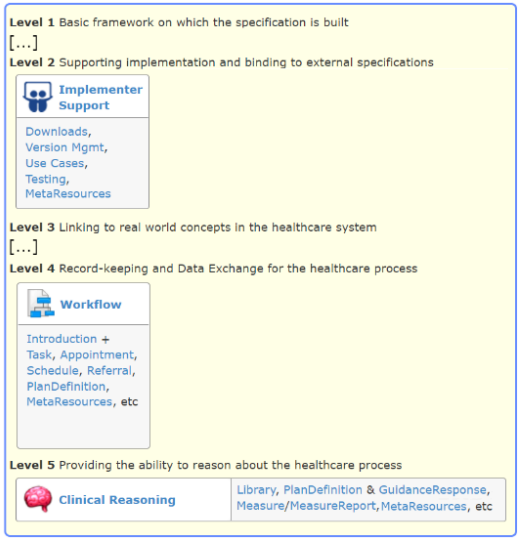
- FHIR modules are the organizational structure of the FHIR specification
  - High-level guidance to implementers: which parts of FHIR model a particular healthcare process
- A module defines several components:
  - Scope and index, Use cases, Security and privacy
- Classified into several levels
  - Levels 1 and 2 provide the technological foundation
  - Levels 3 and 4 contain parts of the standard used to model the healthcare domain's content and processes
  - Level 5 provides the means for reasoning over the information recorded/exchanged in the lower levels
- Approach: Assess high-level impact of meta resource integration into FHIR

FHIR Modules Overview

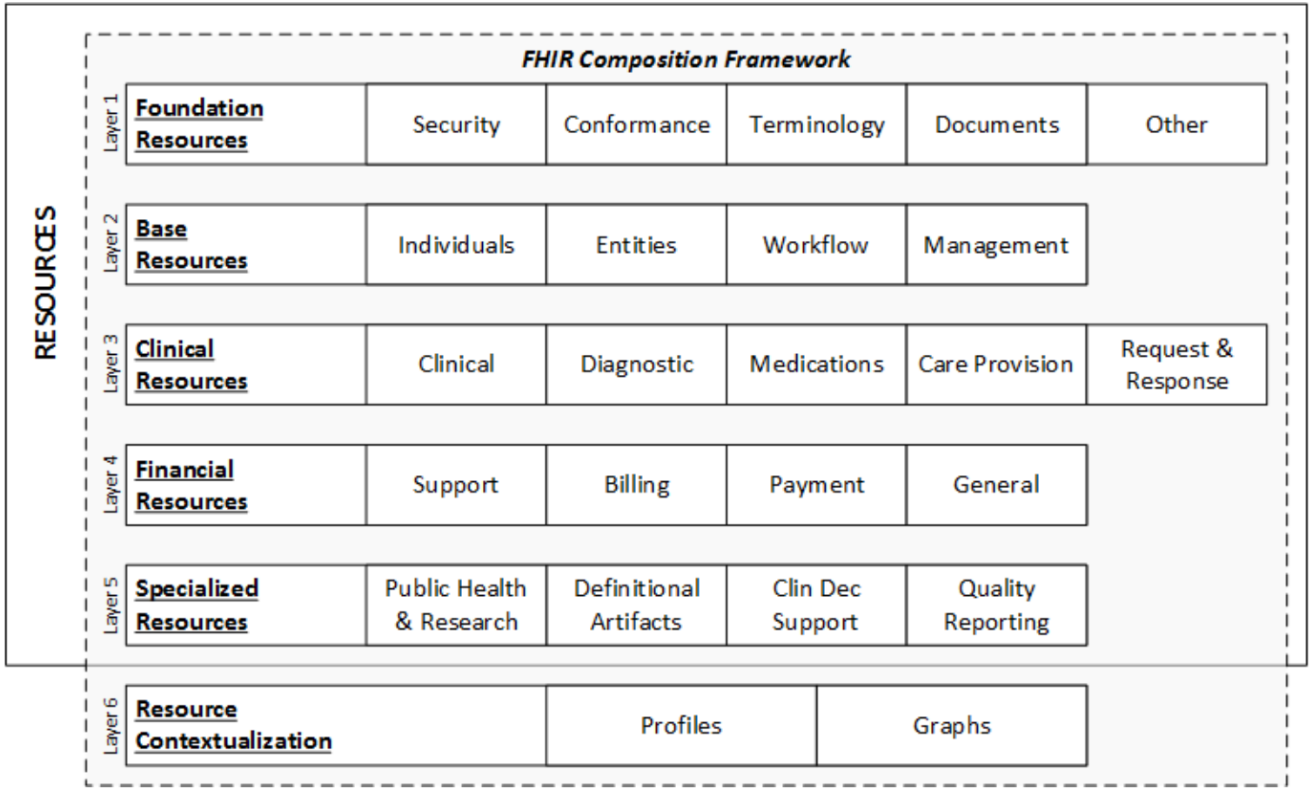


Facet 3: FHIR Modules

- Meta resources crosscut the module classification
- Implementer support module in Level 2
  - Content independent simplification of development process
- Workflow module in Level 4
  - Simplified modeling of generic workflows
- Clinical Reasoning module in Level 5
  - Advanced toolset for managing participating resources



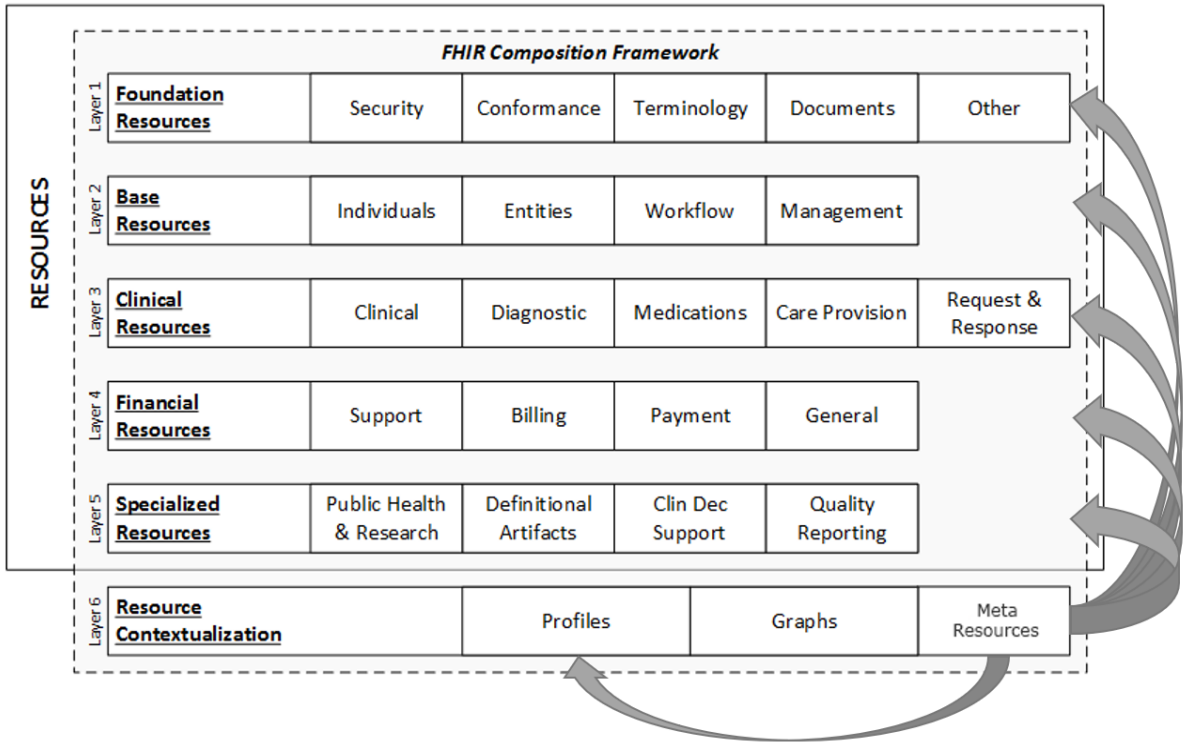
Facet 4: Information Architecture



Facet 4: Information Architecture

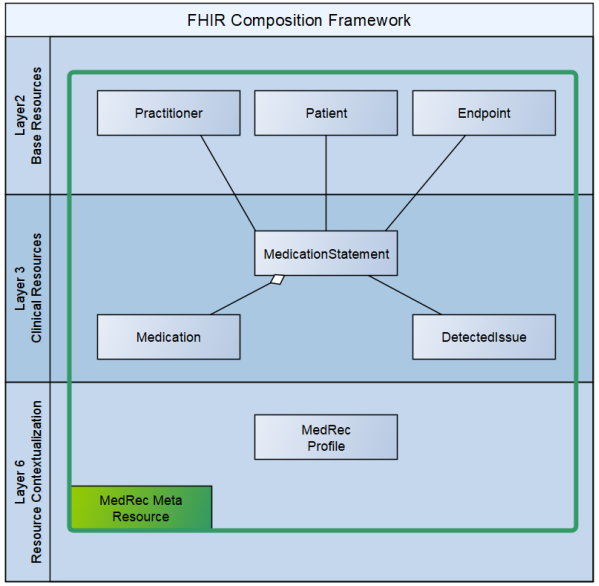
- Resource contextualization Layer 6 of the architecture
  - Designated to adapt FHIR resources to a specific environment
  - No contained resources
  - Represents concepts that extend, constrain, add additional attributes, or provide meta information
- Applies concepts to resources from Layer 1 through Layer 5
- Approach: Assess introduction of meta resources as part of Level 6

Information Architecture Integration



Example: MedRec Participating Resources in FHIR Composition Framework

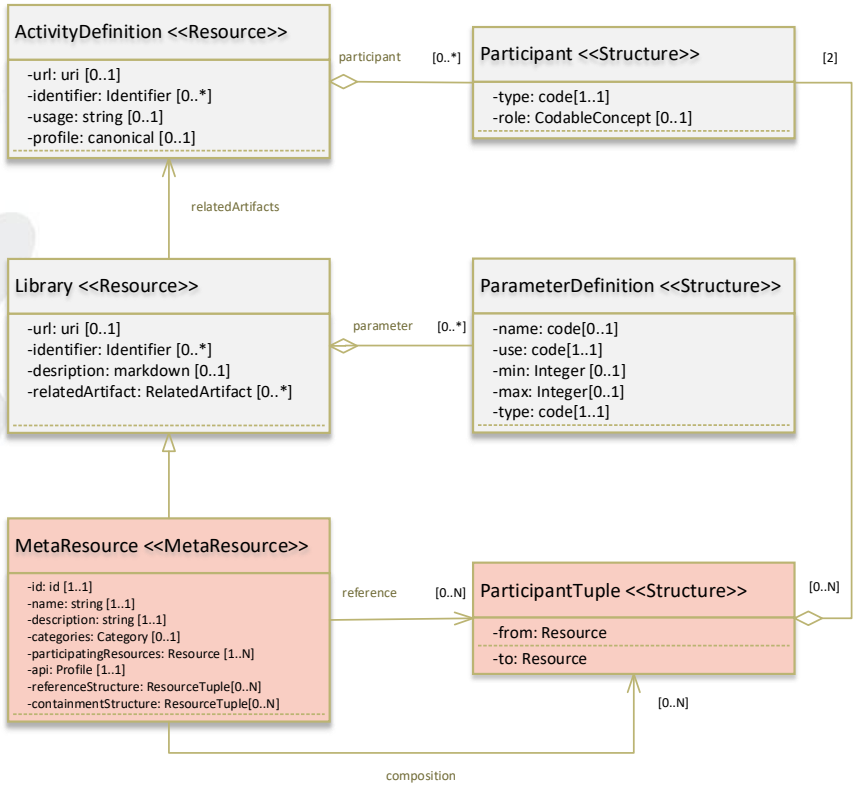
- Patient and Practitioner
  - *Individuals* in Layer 2
- Endpoint
  - *Entities* in Layer 2
- Medication, MedicationStatement, and DetectedIssue
  - *Clinical* in Layer 3
- MedRec FHIR profile
  - *Resource contextualization* in Layer 6



Facet 5: Library + ActivityDefinition Resources

- Library resource
  - General purpose container for expressing & sharing clinical knowledge independently of particular patient
- ActivityDefinition resource
  - Describes an activity in a sharable and (optionally) machine-consumable form
  - Define parts of a workflow, to describe a protocol, or to create a catalog of activities
- Approach: Represent meta resources through a combination of Library and ActivityDefinition

Library and ActivityDefinition Integration



Conclusions

- Extension of the FHIR standard with the concept of a meta resource which allows for a design pattern-like capability to support reusable components
- Definition of a model for meta resources, presented with medication reconciliation example
- Translation of meta resources to bundle schemas, that can be used by during transition from design to development
- Baseline integration into FHIR standard through Bundle generation
- Exploration of five alternative facets for full demonstration of integration capabilities

Ongoing and Planned Research

- **Generation process extension**
  - Consider other potential artifacts based on discussion of the five presented FHIR facets
  - May require changes to the formalization of the meta resource data model
- **Utilization of generated artifacts**
  - Realization of MedicationReconciliation meta resource based on alternative artifact generations
  - Use of artifacts in prototype application based on the MedRec app
  - Demonstrate feasibility and explore limitations