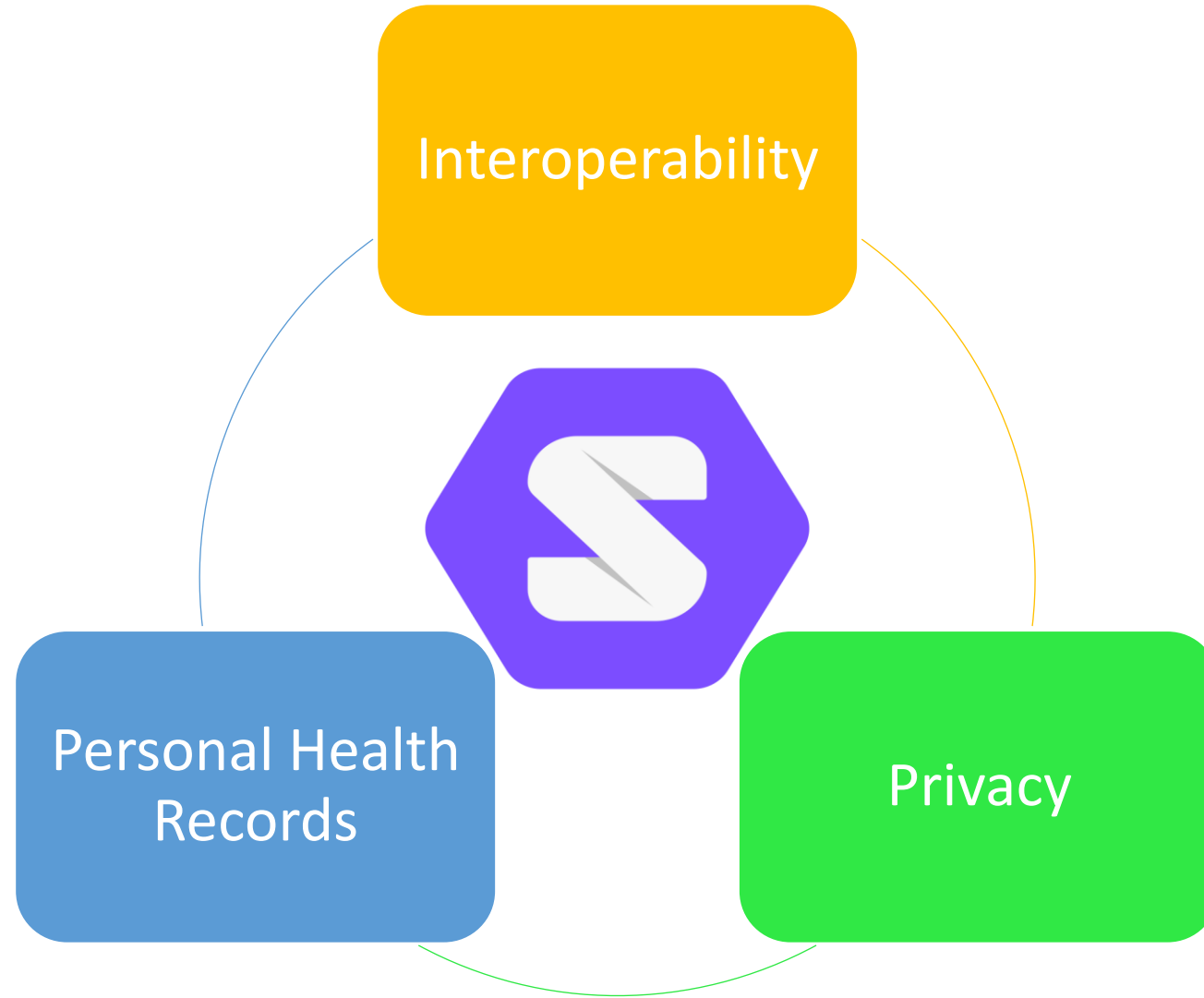


Improving interoperability of
personal dental data while
upholding privacy



A decentralized architecture for sharing dental records



Dental sector landscape

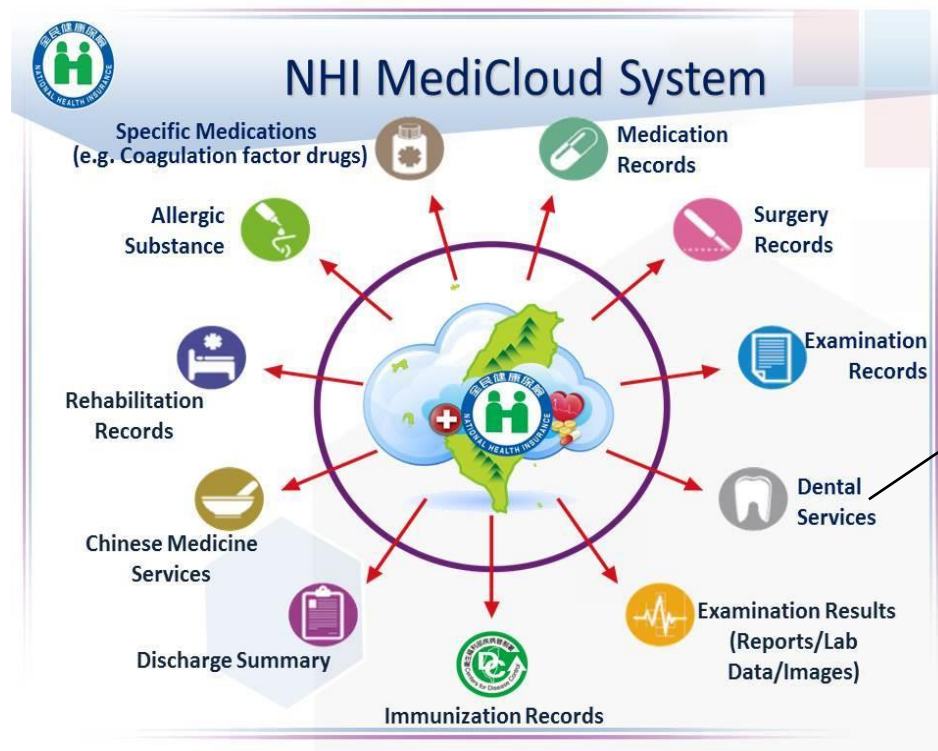
- 91% of active dentists worked in private practice settings
- 46% of private practice dentists were in solo practice
- Lack of human and financial resources
- Technical barriers
 - Incompatibility between different electronic records systems.
 - Data duplication.
 - Outdated data.
 - Scalability issues.
 - Inefficient data processes.

Benefits of using dental data in other areas of medicine

Physicians require dental records:

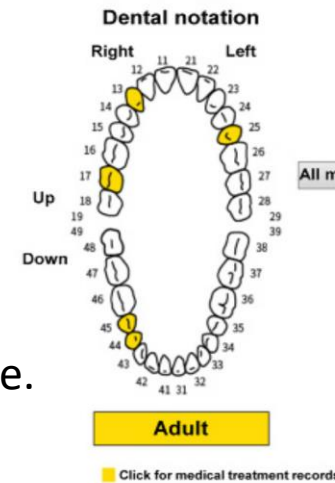
- To diagnose and evaluate systemic diseases and the health status of their patients. More than 200 systemic diseases can present oral symptoms and/or signs
- Monitoring the progress of these diseases
- For coordination and collaboration of healthcare
- For research purposes
- For forensic purposes

Taiwan medical information system - dental data model



Dental treatment and surgical records

1. Medical institution
2. Primary diagnosis
3. Medical order code
4. Medical order
5. Treatment part
6. Start time
7. Finish time
8. Medical order amount
9. Uploaded images inquiry



Medical visit records						
Specific dental treatment <input type="text" value="All"/>						
Selected dental notation <input type="text" value="All"/>						
Sorting item <input type="text" value="Visit date (starting from the earliest)"/>						
Visit date	Medical institution	Primary diagnosis	NHI card sequence number	Medical order code	Medical order	Medical order amount
2017/7/8	You-Yue Dental Clinic	Chronic gingivitis caused by dental plaque	0012	91004C	Scaling-full-mouth	1
2017/7/8	You-Yue Dental Clinic	Chronic gingivitis caused by dental plaque	0012	91014C	Scaling-full-mouth	1
2016/5/3	You-Yue Dental Clinic	Chronic gingivitis caused by dental plaque	0012	91004C	Scaling-full-mouth	1
2016/4/10	You-Yue Dental Clinic	Cavity	0012	89009C	Posterior teeth composite resin restoration-two surfaces	2
2015/12/8	You-Yue Dental Clinic	Cavity at the tooth-enamel level	0012	89005C	Anterior teeth composite resin restoration-two surfaces	1

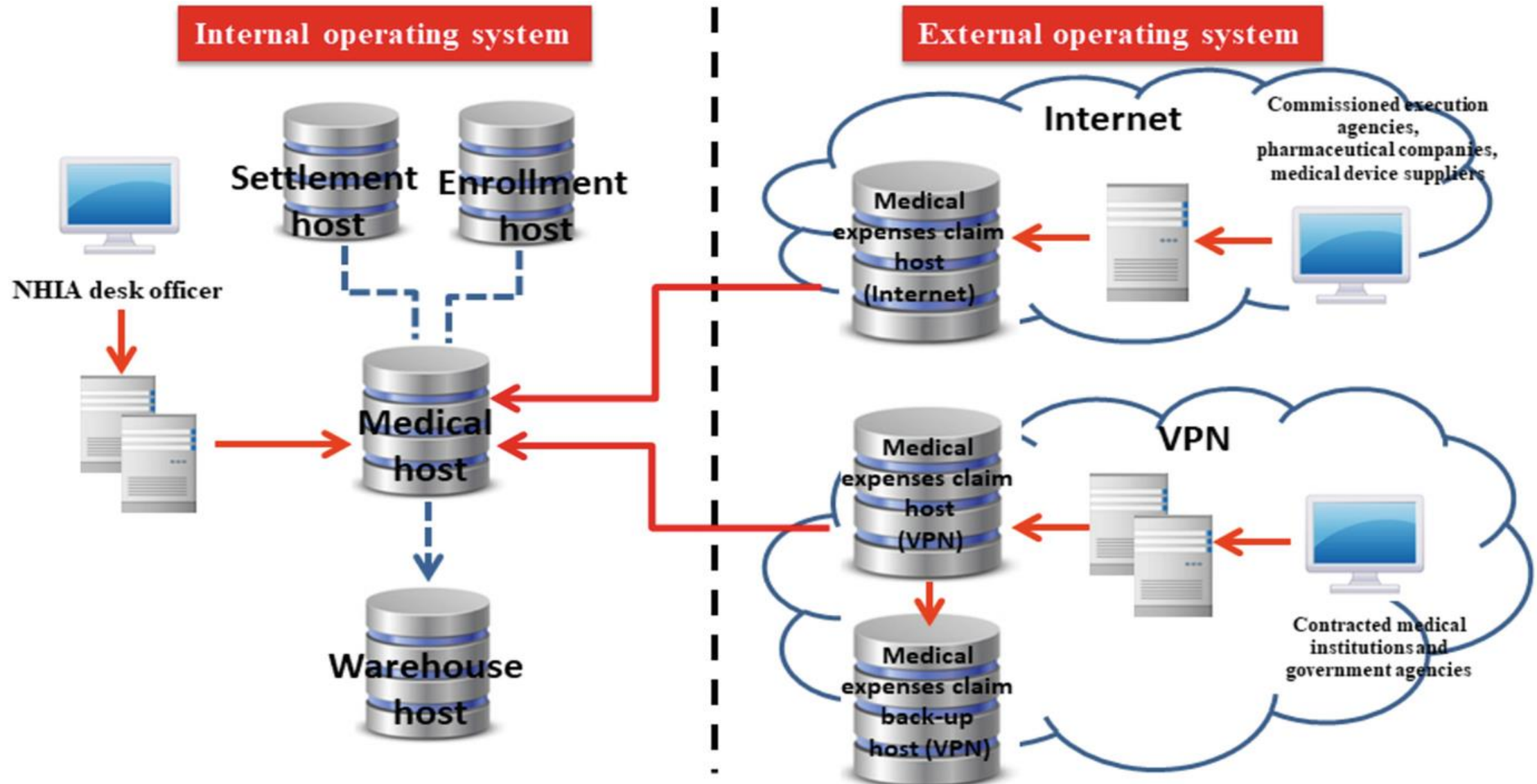
There is no balance in data control between stakeholders.

This architecture depends on the availability of a central node.

Data model defined by the government : There is no interoperability and restricts what information is stored

Source: National Health Insurance Administration, Ministry of Health and Welfare, R.O.C. (Taiwan). IMM_UserGuild_NEW_V3.3.

Taiwan medical information system - architecture diagram



EHR VS PHR

Electronic Health Data

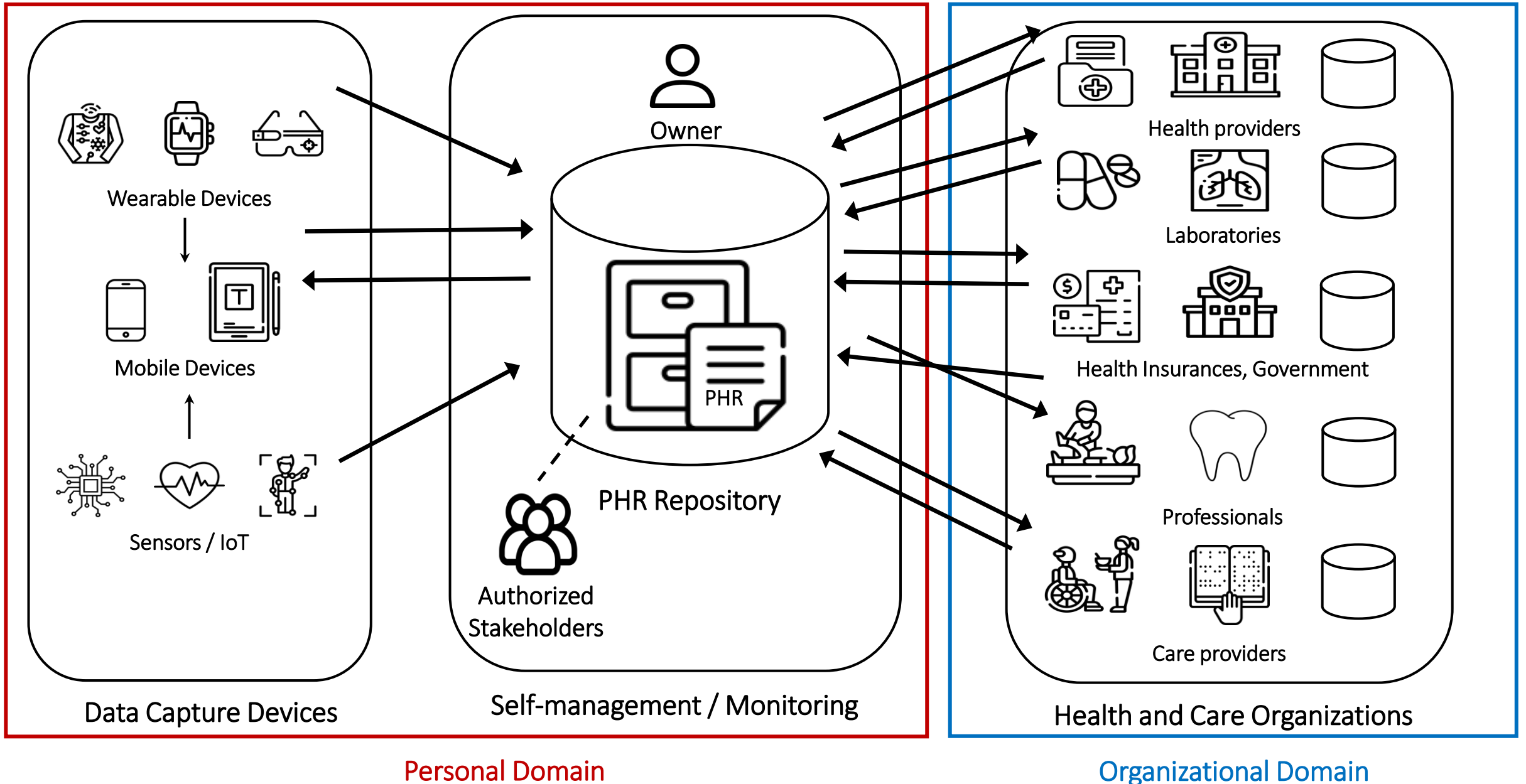
- Designed for professional use
- Different data sources can coexist
- Store clinical data

Personal Health Records

- Used by individuals
- One unique source of data
- Store health data and well-being

	Electronic Health Data	Personal Health Records
Goal	Professional activity performance	Data self-management
Common technologies	Information repository	Set online tools
Competition in management	Professionals	individuals

PHR approach



Some PHR tools

PHR name	Website for PHR
Avado	http://www.avado.com
My Doclopedia	http://www.doclopedia.com
Dr. I-Net	http://www.drinet.com
Mayo Clinic Health Manager	http://healthmanager.mayoclinic.com
HealthVault	http://www.healthvault.com
HealthyCircles	https://connect.healthycircles.com/Public/Consumer/Home.aspx
Juniper Health	http://juniperhealth.com
Koozala	http://www.koozala.com
Lifeclinic	https://www.lifeclinic.com/member/login/login.asp
Mymediconnect	http://www.mymediconnect.net
Medsfile	http://www.medsfile.com
MyMedSafe	http://www.vitalesafe.com
Myphr.ca	http://myphr.ca
NoMoreClipboard	http://www.nomoreclipboard.com
Patient Power	http://gtipatientpower.com
RelayHealth	http://app.relayhealth.com
YourHealthRecord	http://www.yourhealthrecord.com
WebMD Health Manager	http://www.webmd.com/phr
ZebraHealth	https://www.zebrahealth.com/PersonalHealthRecord/Personal_Health_Records.ztml

Data availability depends on application availability.

Data model defined by companies: There is no interoperability and restricts what information is stored

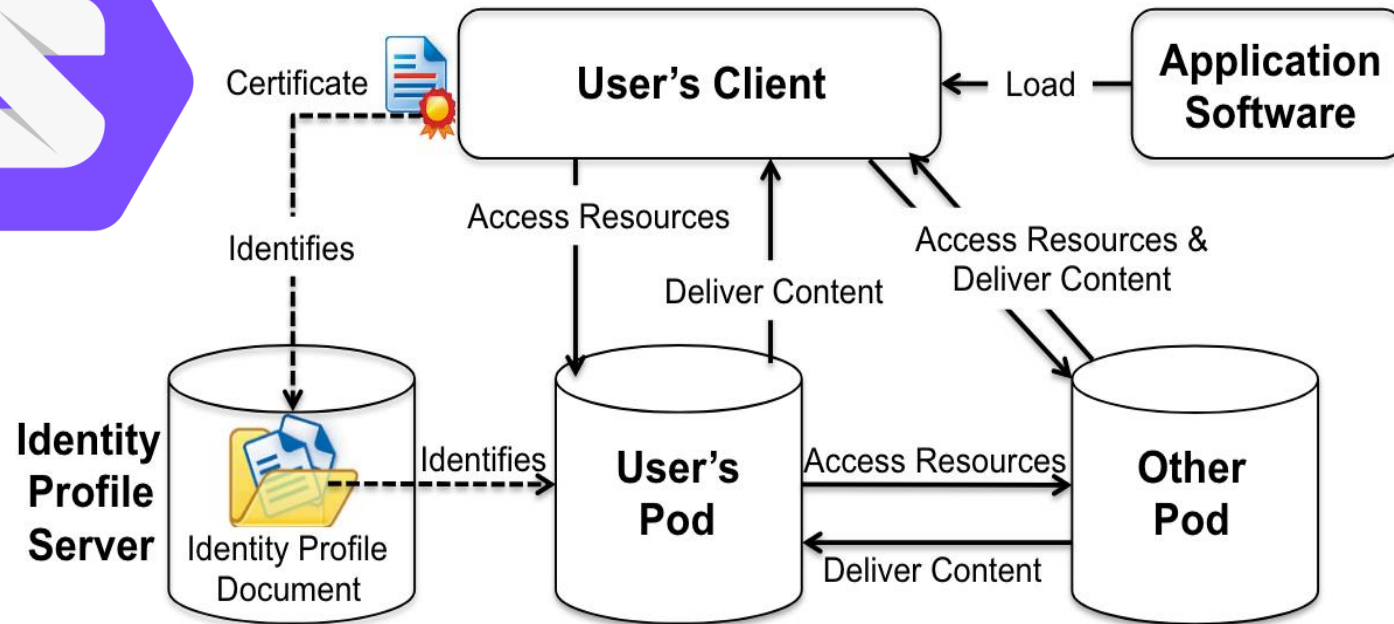
“Substitute applications”

Individuals must enter data.

Individuals still have no control over their health data

DEPRECATED

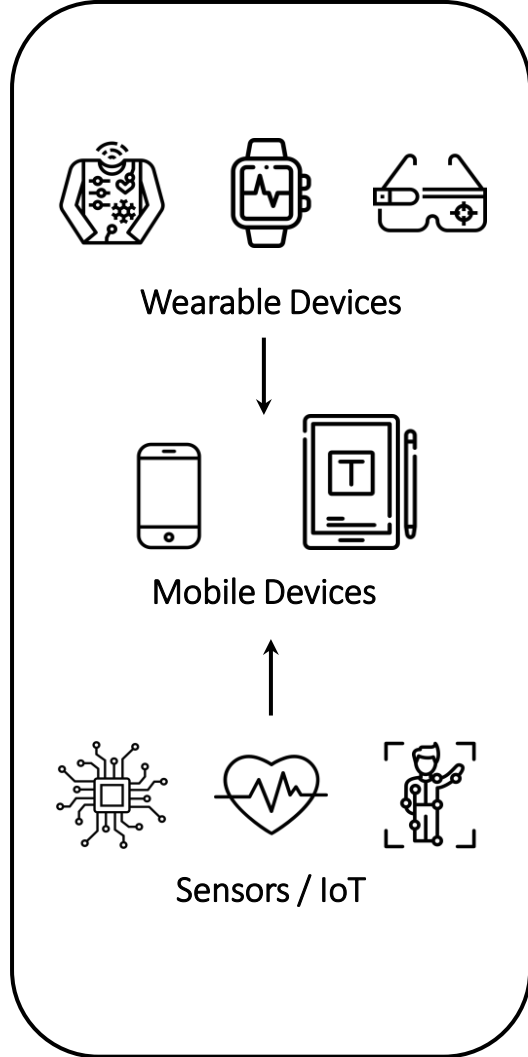
Solid: Social Linked Data Platform



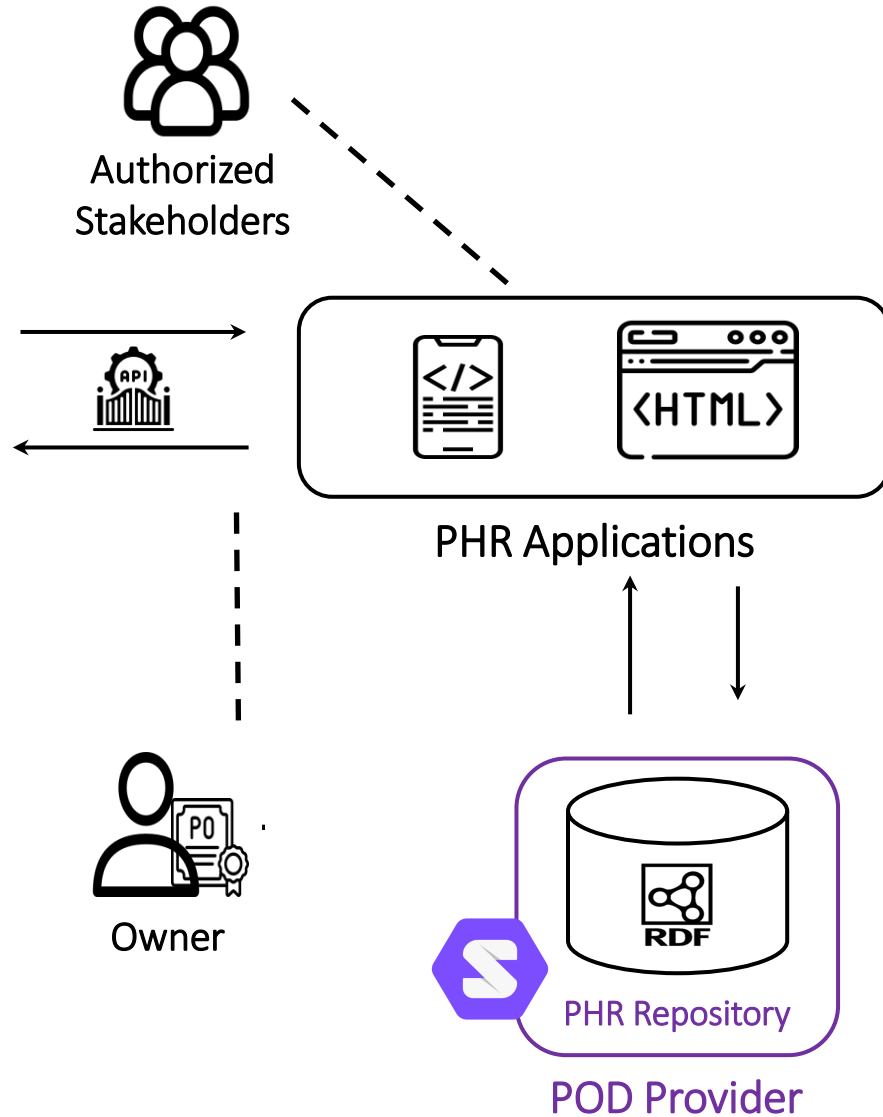
Main advantages of Solid

- Allows Interoperability
- Brings Security & Privacy
- Enables Data Portability
- Gives users control over their data
- User empowerment

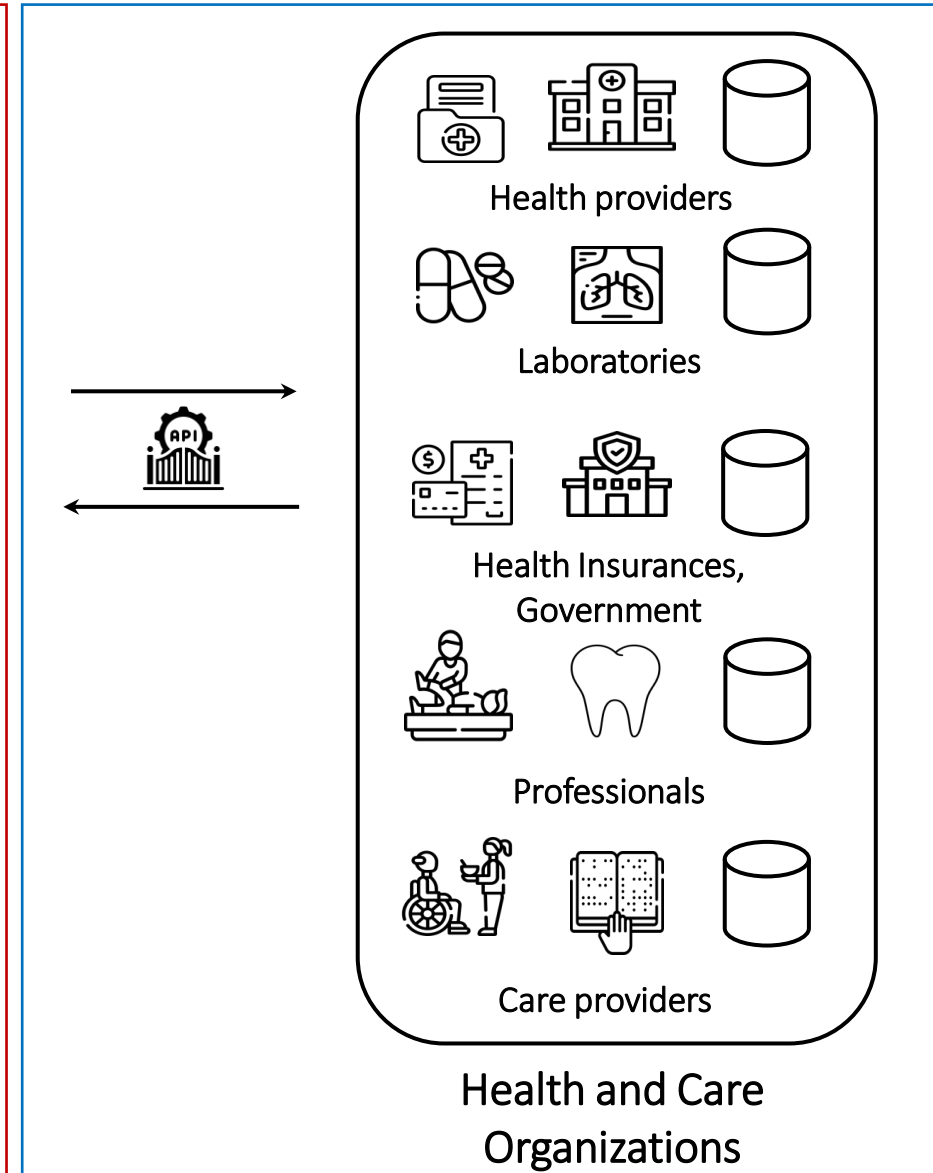
General architecture diagram



Data Capture Devices



Personal Domain



Organizational Domain

Privacy

Principles



- **Privacy:** In medical ethics, the concept is associated with maintaining a patient's dignity and **autonomy** and with the doctor's duty of **confidentiality**.
- **Autonomy:** Literally 'self-rule', the capacity for reasoned self-determination in thought and action. There is not unlimited.
- **Confidentiality:** Ethical and legal obligation that requires doctors to keep information about their patients private.

Concise Medical Dictionary
(Oxford Quick Reference).

Laws & Standards

- HIPAA – GINA laws (USA)
- ISO 27799
- Regulation 2016/679 - General Data Protection Regulation



Security measures

Security Requirements

- Confidentiality
- Integrity
- Availability

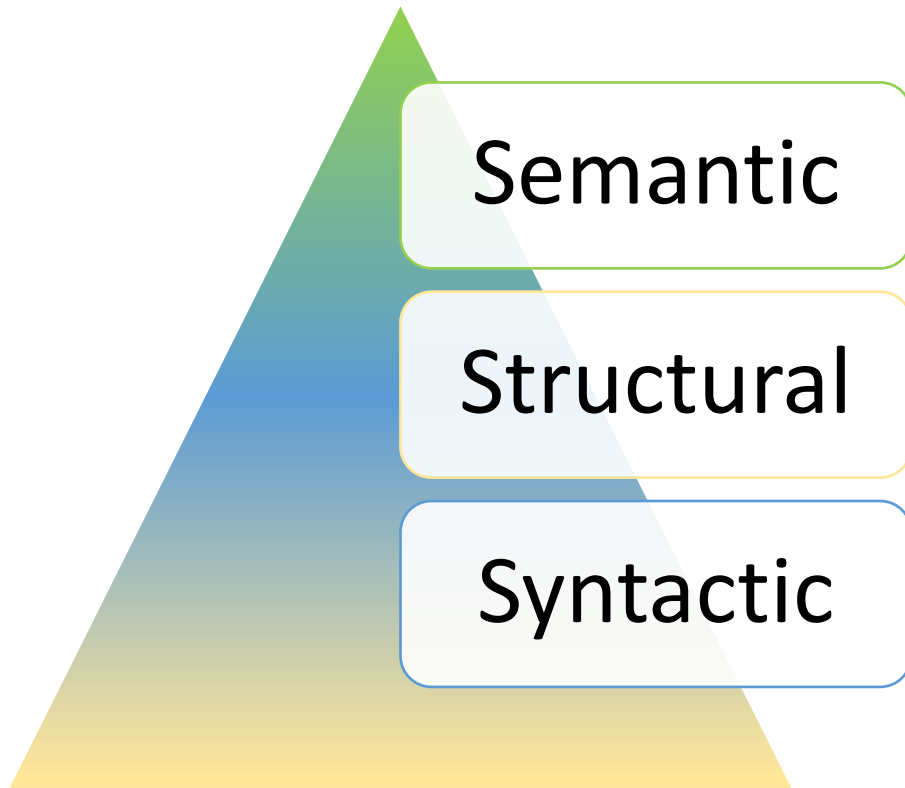


Security Measures

- Access control policies
- Role system
- anonymization techniques
- encryption technics

Interoperability

“The ability of two or more systems or components to exchange information and to use the information that has been exchanged”- IEEE



Autonomy issues

- The data or information being managed (domain).
- The **representation** (data model, query language) and the **naming** of the data elements (or the ontology used)
- The **conceptualization** or semantic interpretation of the data (or the context).
- **Constraints** used to manage the data.
- The functionality of the system.
- Association and sharing with other systems.

Interoperability



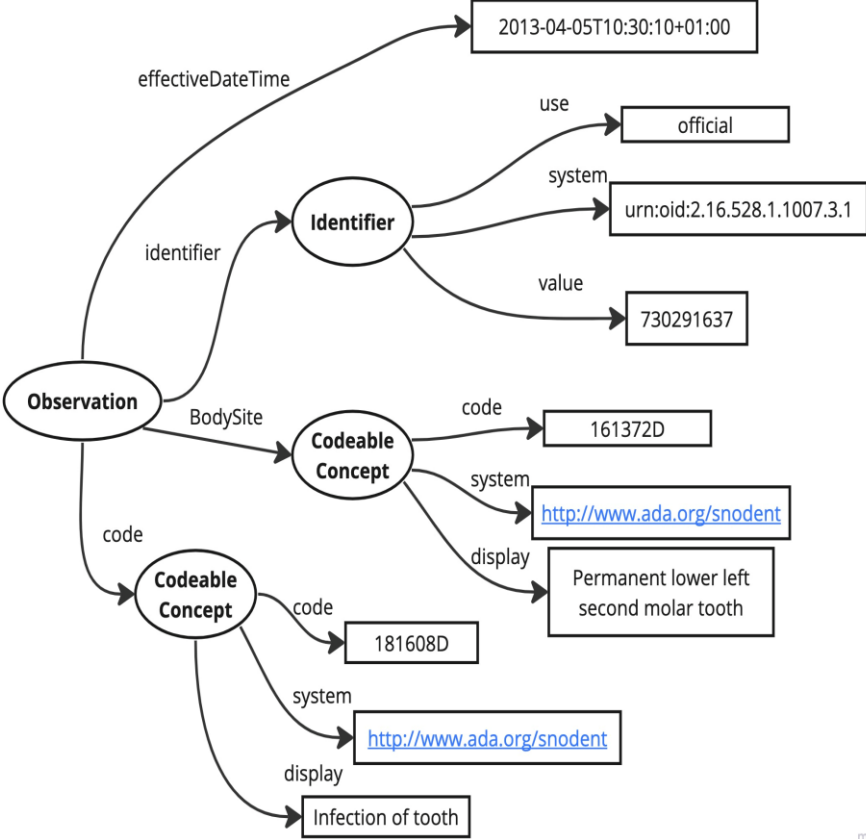
RDF is the recommended format for sharing health data due to its semantic interoperability, granular representation, and alignment with linked data principles, enabling efficient integration and exchange of diverse healthcare information.



FHIR is one of the most widely used standardized formats for health information exchange. It has resources to define standards for bi-directional information exchange between a medical and a dental provider or between dental providers.



SNOMED CT is a comprehensive clinical terminology used globally for standardized healthcare data encoding.



miro

Representation of a knowledge graph

Interoperability



Shape Expressions (ShEx) is a language that allows modeling graphs (sets of RDF triples) in a precise and formal way.

ShEx allows us to define the topology of the stored data. A fundamental requirement when we are trying to represent complex entities.

These schemas facilitate an inference testing service, employing the provided schema on the input graph, and employing a reasoning mechanism capable of deducing requisite transformations to adapt the information to the output model, through the addition of new triples and execution of transformations.

```
PREFIX :           <http://example.org/clinic>
PREFIX schema:    <http://schema.org/>
PREFIX xsd:       <http://www.w3.org/2001/XMLSchema#>

:Observation {
  :identifier      IRI @:Identifier;
  :effectiveDateTime xsd:date? ;
  :BodySite       IRI @:CodeableConcept;
  :code           IRI @:CodeableConcept;
}

:CodeableConcept {
  :code          xsd:string ;
  :system        xsd:string ;
  :display       xsd:string ;
}

:Identifier {
  :use           xsd:string ;
  :system        xsd:string ;
  :value         xsd:string ;
}
```

Representation of a Shape Expression

Interoperability: An example with Legos

```

PREFIX :      <http://example.org/clinic>
PREFIX schema: <http://schema.org/>
PREFIX xsd:    <http://www.w3.org/2001/XMLSchema#>

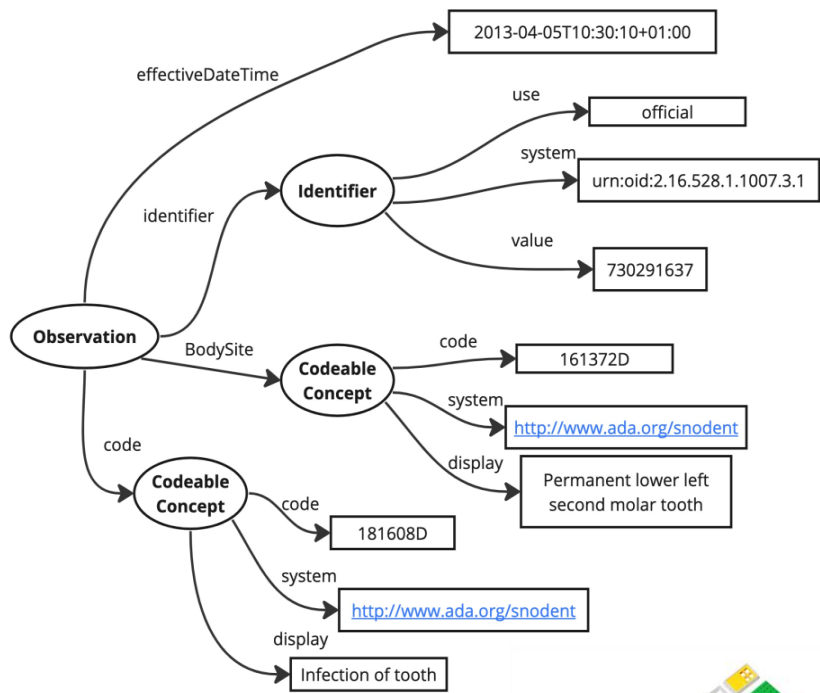
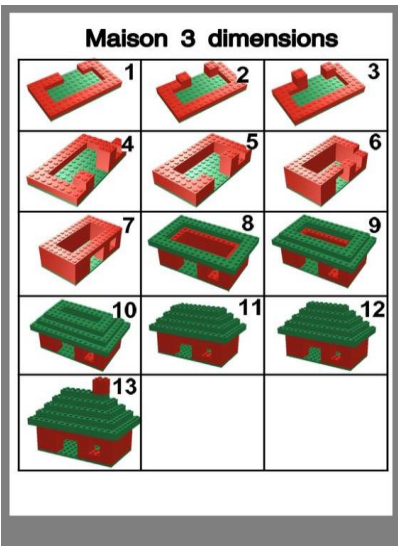
:Observation {
  :identifier      IRI @:Identifier;
  :effectiveDateTime xsd:date? ;
  :BodySite       IRI @:CodeableConcept;
  :code           IRI @:CodeableConcept;
}

:CodeableConcept {
  :code      xsd:string ;
  :system    xsd:string ;
  :display   xsd:string ;
}

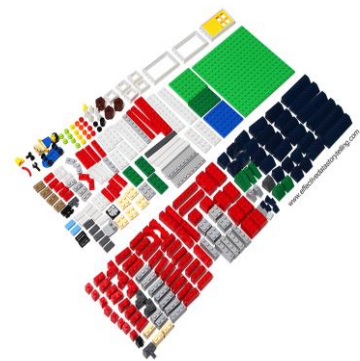
:Identifier {
  :use      xsd:string ;
  :system   xsd:string ;
  :value    xsd:string ;
}
    
```

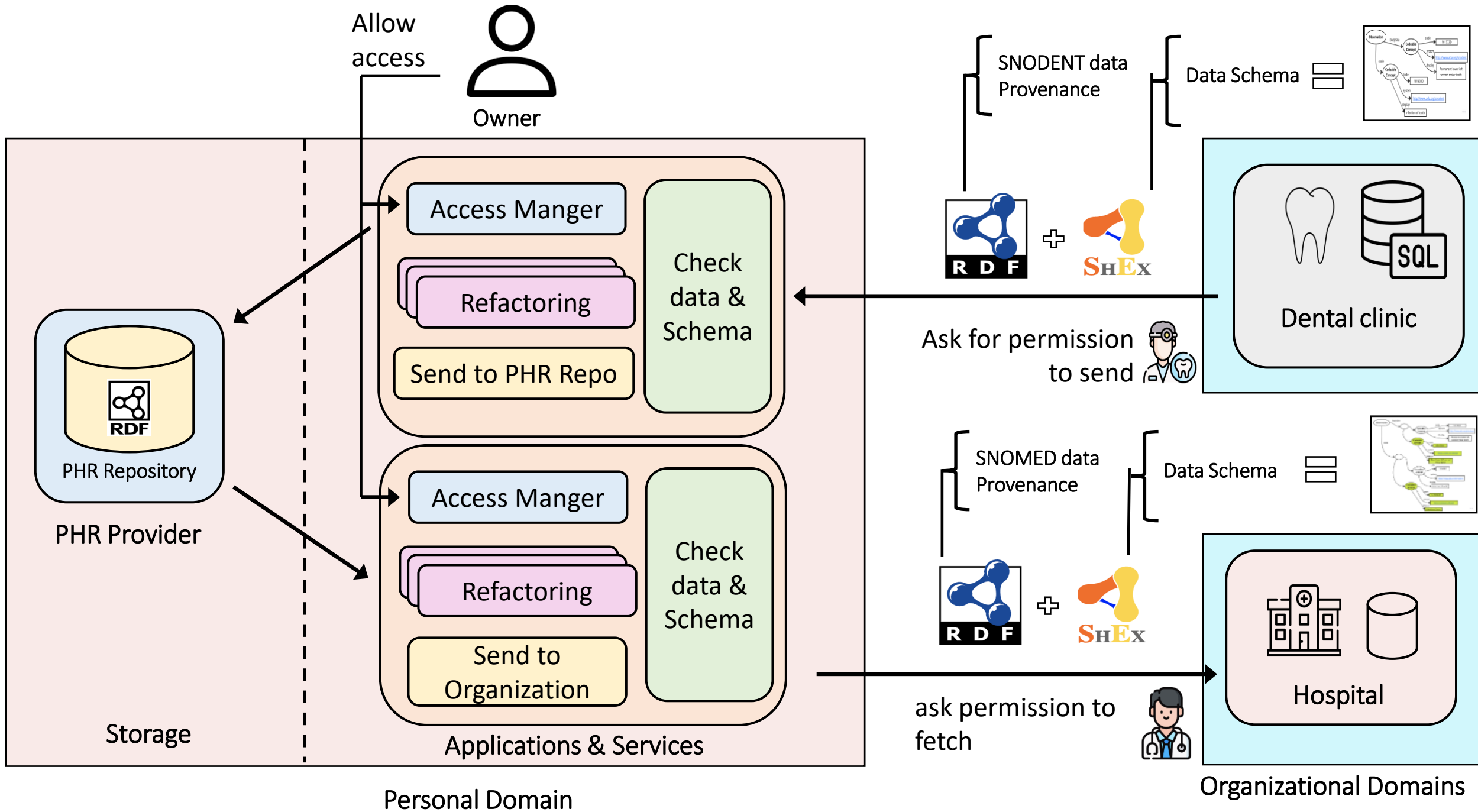


Shape Expression

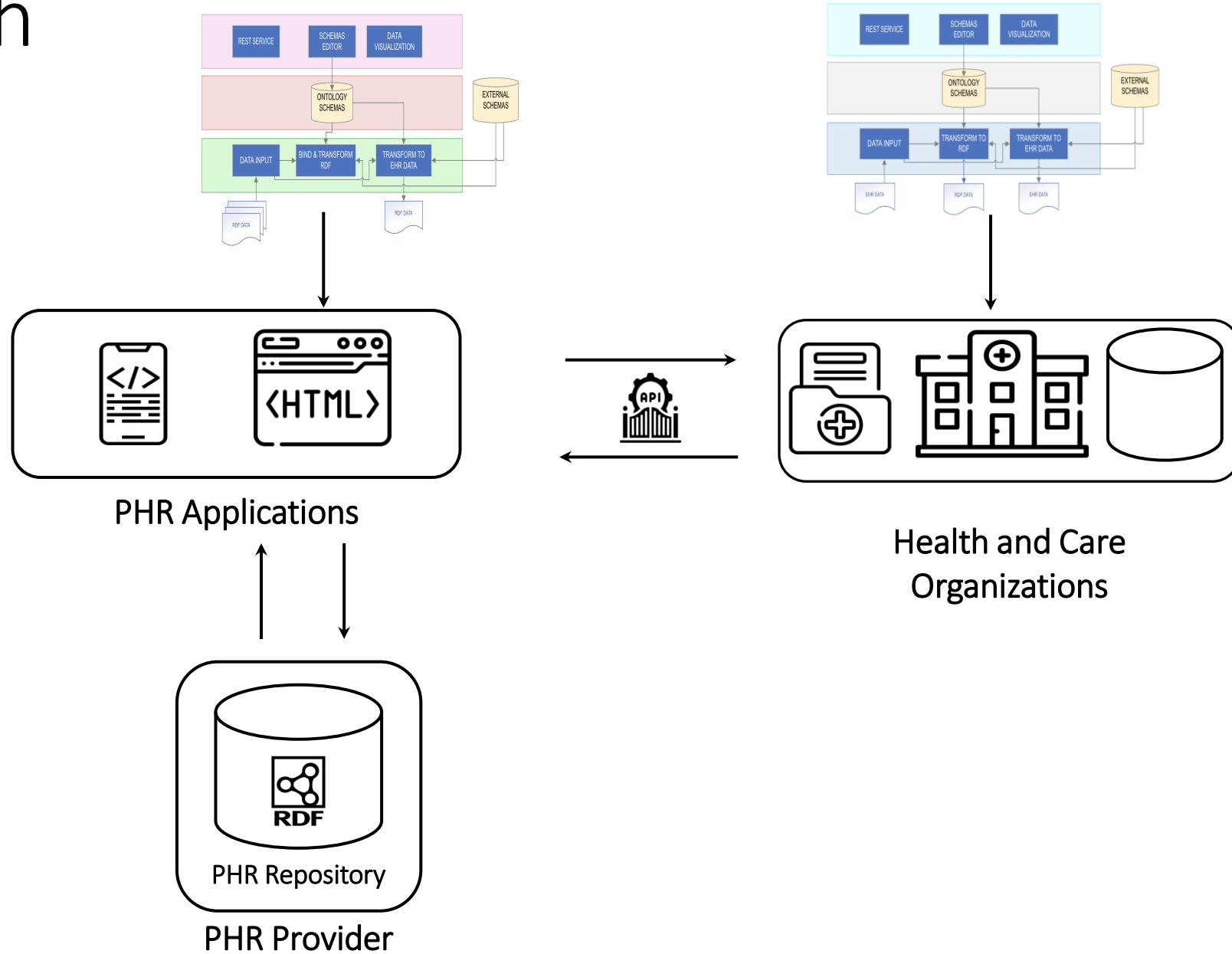


RDF Graph

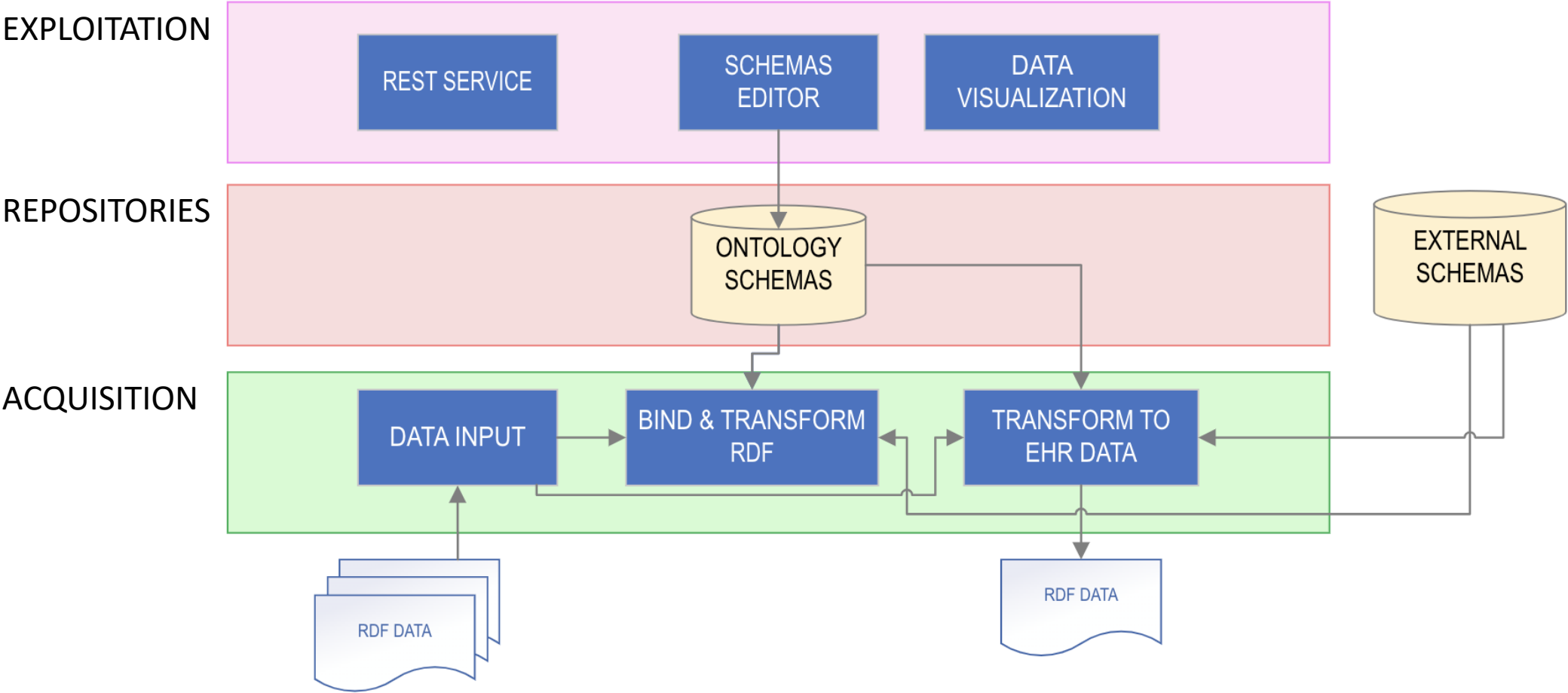




Approach



User side layer



References

- Fellows, Jeffrey & Atchison, Kathryn & Chaffin, Jeffrey & Chávez, Elisa & Tinanoff, Norman. (2022). Oral Health in America. The Journal of the American Dental Association. 153. 10.1016/j.adaj.2022.04.002..
- (Mary) Tai, HY., Wu, SH. (2022). Infrastructure of the Medical Information System. In: Lee, PC., Wang, J.TH., Chen, TY., Peng, Ch. (eds) Digital Health Care in Taiwan. Springer, Cham. https://doi.org/10.1007/978-3-031-05160-9_6
- Chiang, Hsiang-Tsai & Chang, Chiu-Ta. (2019). Introduction to and Application Analysis of Taiwan's NHI-MediCloud System. Journal of Service Science Research. 11. 93-115. 10.1007/s12927-019-0005-6.
- Torres-Urquidy, M.H., Powell, V., Geist, SM.R.Y., Mishra, S., Chaudhari, M., Allen, M. (2019). Health Information Technology Considerations of Medical and Dental Data Integration. In: Acharya, A., Powell, V., Torres-Urquidy, M., Posteraro, R., Thyvalikakath, T. (eds) Integration of Medical and Dental Care and Patient Data. Health Informatics. Springer, Cham. https://doi.org/10.1007/978-3-319-98298-4_11
- Vujicic, M., & Fosse, C. (2022). Time for Dental Care to Be Considered Essential in US Health Care Policy. AMA journal of ethics, 24 1, E57-63 .
- Lebrede, Hugo et al. "A Decentralized Architecture for Semantic Interoperability of Personal Dental Data Based on FHIR." Int. J. Semantic Web Inf. Syst. 19 (2023): 1-16.
- Thornton, K. et al. (2019). Using Shape Expressions (ShEx) to Share RDF Data Models and to Guide Curation with Rigorous Validation. In: Hitzler, P., et al. The Semantic Web. ESWC 2019. Lecture Notes in Computer Science(), vol 11503. Springer, Cham. https://doi.org/10.1007/978-3-030-21348-0_39
- Solbrig, Harold & Prud'hommeaux, Eric & Grieve, Grahame & McKenzie, Lloyd & Mandel, Joshua & Sharma, Deepak & Jiang, Guoqian. (2017). Modeling and validating HL7 FHIR profiles using semantic web Shape Expressions (ShEx). Journal of Biomedical Informatics. 67. 10.1016/j.jbi.2017.02.009.