A Storage as a Service scheme for supporting Medical Services on 5G Vehicular Networks

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***Abstract*—Vehicular networks have emerged in recent years offering novel medical services to vehicular users. In-vehicle equipment such as On-Board Units (OBUs), Internet of Things (IoT) devices and sensors are used to supervise the health of on-board users and create an increasing amount of medical information. This information should be processed and then transmitted to medical units (e.g. hospitals) with the lowest possible processing and communication delays. Furthermore, it should be organized considering well-defined standards, in order to be easily reusable from third-party medical systems. Thus, the medical staff will be able to remotely provide immediate medical support to vehicular patients. In this paper, an interoperable Storage as a Service (STaaS) scheme which delivers medical data through a 5G wireless network architecture is described. The Health Level 7 (HL7) standard is applied for the manipulation of the collected medical data, ensuring the interoperability of the proposed scheme with third-party systems that use the same standard. The Web Ontology Language (OWL) is used to produce and manipulate the relative ontological descriptions about the collected data.**

***Index Terms*—5G Vehicular Networks, Cloud Computing, Fog Computing, Medical Services, Health Level 7 (HL7), Web Ontology Language (OWL), Storage as a Service (STaaS)**

I. INTRODUCTION

Nowadays, the volume of medical data is increasing rapidly, as the delivery of medical services to vehicular users has become a common task. Storage as a Service (STaaS) [1] schemes provide the capability to store data in virtualized environment, while virtualization of resources allows multiple users to coexist and deploy their data on the same underlying storage infrastructure. Data isolation is achieved since each user obtains access only to his own storage resources, which has no interconnection with the resources of the other users that work simultaneously on the same physical infrastructure. Also, efficient utilization of the available physical resources is succeeded, since each user commits dynamically only the required resources, reducing the waste of unnecessary resources.

In the modern vehicular environment, strict constraints of medical services (e.g. minimal communication delays) should be satisfied, since such services are usually used from patients with critical health status. In this environment, 5G Vehicular Cloud Computing (5G-VCC) can be applied to deploy the appropriate communication infrastructure for supporting the medical services which are provided to smart vehicles.

5G-VCC combines the operating principles of both Vehicular Networks and Cloud computing, inducing the evolution of the 5G approach. In a typical 5G-VCC system, vehicles are equipped with On-Board Units (OBUs) with computational, storage and communication resources. Also, vehicles communicate with each other as well as with Road Side Units (RSUs), which construct Fog infrastructures [2]. Each RSU can also interact with a Cloud infrastructure which deploys a variety of medical services with strict Quality of Service (QoS) requirements. Each vehicle could serve many passengers with different services and various requirements.

In this environment, the interoperability of the collected medical data is an important factor that should be satisfied. In particular, the collected medical data should be organized considering well-defined standards, in order to be easily reusable from third party medical systems. To address such interoperability issues, the Health Level 7 (HL7) [3] standard can be applied for the manipulation of the collected medical content. Specifically, HL7 is a set of standards designed to transfer various data (such as administrative, medical or clinical data) between different software applications used by health care providers. Medical institutions and hospitals, use different systems for monitoring the health status of patients. Cooperation between systems for data renewal and the integration of new information is therefore necessary. This collaboration is defined by HL7 through a set of rules and methodologies. Furthermore, HL7 consists of the Version 2.x Messaging Standard, the Version 3 Messaging Standard, the Clinical Document Architecture (CDA), the Continuity of Care Document (CCD), the Structured Product Labeling (SPL) and the Clinical Context Object Workgroup (CCOW). Specifically, Clinical Document Architecture (CDA) aims in the exchange of the structure and encoding of clinical documents. The Continuity of Care Document (CCD) is mainly a United States' standard for medical record exchange. According to HL7 version 3, the Structured Product Labeling (SPL) contains a medicines' every available information. The Clinical Context Object Workgroup (CCOW) is a real-time protocol that allows various applications to access and share user and patient data.

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Additionally, the main purpose of HL7 Version 2.x Messaging Standard is to define a form of interoperability for both medical and non-medical transactions. It consists of an electronic messages sequence that uphold various procedures such as clinical, logistic, and financial. Also, HL7 Version 3 Messaging Standard uses XML encoding and aims at supporting each and every function and flow of the medical care system.

Ontological description of medical information is also a useful factor that enhances the overall usability of medical services. In general, the Resource Description Framework Schema (RDFS) [4] provides structures for knowledge representation. It deals with the organization of ontological hierarchies such as classes, relationships and properties. However complex structures or restrictions such as the scope of properties or the cardinality of attributes cannot be supported in RDFS. The need of a more powerful ontology language leads us to Web Ontology Language (OWL) [5], [6]. Specifically, OWL is a family of knowledge representation languages used for composing ontologies. It is considered as an extension of the RDFS and its specifications have been authorized by the World Wide Web Consortium (W3C). Ontologies are described in OWL documents by defining classes, properties and individuals. Classes are collection of concepts, attributes are properties of classes and individuals represent the objects of a particular class.

SPARQL [7], [8] is also used for querying the medical data and the relative ontologies. SPARQL is an SQL-like language developed for issuing queries [9] to RDF and OWL repositories. Queries are expressed in triple patterns similar to RDF whereas RDF subjects, predicates and objects could be variables. Additional language features include conjunctive or disjunctive patterns as well as value filters. SPARQL components are described in three specifications. The query language specification [10] describe the SPARQL language structures. The query results XML specification [11], defines the format of the results returned from SPARQL queries as XML documents. The SPARQL protocol [12] defines the framework for sending queries from clients to remote server using HTTP or SOAP messages.

In this paper, a prototype Storage as a Service (STaaS) scheme which is deployed to a 5G-VCC architecture is proposed. It delivers interoperable medical information to both vehicular users/patients and remote medical staff. The manipulation of the medical data is performed using OWL ontologies, which provide semantic descriptions of the medical content. Finally, SPARQL is used for querying the used medical data and the relative OWL ontologies.

The remainder of the paper is as follows: Section II discusses the related work, while section III describes the system architecture of the proposed scheme. Then, section IV presents a case study. Finally, section V evaluates the implemented system architecture and section VI concludes the discussed work.

II. Related Work

The rapid increase in medical content has challenged the academic and industrial communities into the development of Information and Communications Technology (ICT) tools for data manipulation in order to extract useful conclusions about patients' health.

Indicatively, in [13] a Health Monitoring System (HMS) is proposed. In this case, Internet of Things (IoT) devices collect medical data from patients' bodies. A Fog [14] infrastructure provides the required storage equipment for the collected data. Then, the Fog applies data mining techniques to prevent cardiac diseases that could occur to each monitored patient.

Likewise, in [15] a Fog infrastructure for Medical Data Manipulation (Fog-MDM) is described. In the proposed scheme, body sensors collect medical data about patients. Then, the collected data are transmitted to the Fog infrastructure which analyses them and extracts clinical conclusions. Specifically, as case study, the authors described a medical application which collects data from the sensors and transmits warnings to patients with speech motor disorders or cardiovascular problems. Experimental results showed the Fog infrastructure improves the system response times.

However, the aforementioned works do not apply any well-defined way for the storage, the transmission and the manipulation of the collected data. Thus, their interoperability with third-party tools is quite limited. To address such interoperability issues, an increasing number of these implementations use well-defined standards. In general, the HL7 is considered as the main standard for storing, organizing and delivering medical information.

In [16] the concept of Personal Health Records (PHRs) is studied. PHRs are described as an extension of Electronic Health Records (EHRs) [17]. They allow patients to record, access and manipulate their health data, by applying the HL7 standard. Thus, interoperability with third party tools that comply with the HL7 is ensured. It allows medical staff with compatible tools to immediately make the appropriate clinical decisions about patients' health. Also, it should be noted that the entire communication is bi-directional, since the patients can realize any change to their diagnostics in real-time. The capabilities of the HL7 Fast Healthcare Interoperability Resources (FHIR) [16] are demonstrated. The PHR data are organized as FHIR assets and become available to both patients and medical staff.

In [18] the Open Archive Information System (OAIS) scheme for managing HL7 data, is described. The OAIS scheme is widely used in hospitals for the manipulation of both medical staff and patients' data. A case of study of HL7 glucose observations in JSON format [19] is considered. The authors demonstrate that an archival storage for HL7 data manipulation is more appropriate for hospitals, in comparison with the use of traditional Relational Database Manipulation Systems (RDBMS) [20].

Another work that uses the HL7 standard is described in [21]. The interoperability between Cloud and Fog infrastructures that manipulate HL7 data is studied. Specifically, a framework to exchange Medical Information between Medical Entities (MIME) running on both Cloud and Fog equipment is proposed. The authors mention that the HL7's focus, along with the manipulation of PHRs, has extended to regional Cloud infrastructures and to Fog infrastructures emerging from Body Area Networks (BANs) [22] that monitor patients' health factors. For the demonstration of the proposed framework, the authors implemented a software tool which exchange HL7 information using ZigBee [23] and WiFi [24] communication technologies.

As it will be described in the next sections, the system architecture proposed in this paper combines the advantages of the aforementioned works. Specifically, a 5G network architecture that combines both Cloud and Fog infrastructures is proposed. Furthermore, the manipulation of the medical data is performed according to the HL7 standard which enhances the interoperability of the proposed scheme with third party medical systems.

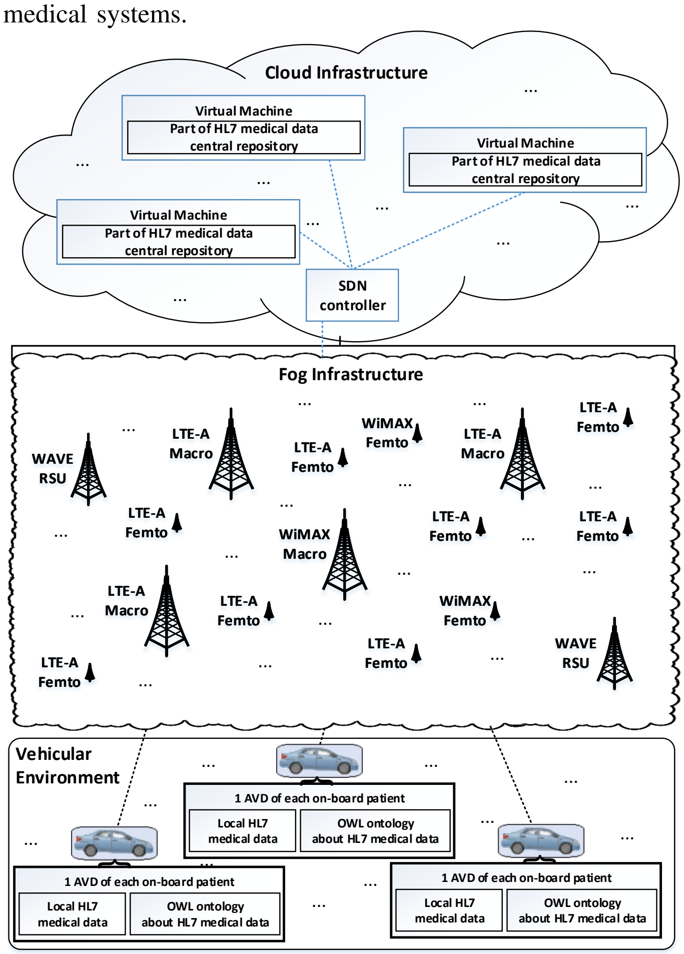

Fig. 1: The system architecture.

III. The Design of the Proposed Scheme

The proposed Storage as a Service (STaaS) scheme is deployed to the 5G-VCC architecture presented in Figure 1. The architecture includes a vehicular environment, a Fog and a Cloud infrastructure.

Regarding the vehicular environment, the functionality of the NS3 [25] simulator has been extended in order a virtualized environment to be implemented in each vehicle. Specifically, the OBU of each vehicle hosts multiple Android Virtual Devices (AVDs) [26]. An AVD is created for each on-board patient (namely for each vehicular user), providing isolation for the manipulation of his medical data. Also, the resources of each AVD can be dynamically adjusted according to the requirements of each patient, enhancing the utilization of the available on-board physical resources. Additionally, each AVD hosts the HL7 medical data about the corresponding on-board patient as well as the relative OWL ontology describing the semantics of the aforementioned HL7 medical data. Specifically, the $RiskAssessment$ element of the HL7 standard is considered. A sample of this element is presented in Table I indicating medical information about each user. This information includes both general and clinical data. The general data indicate the age and the gender of the user, as well as if the user is a smoker. Correspondingly, the clinical data indicate the user cholesterol levels, his systolic blood pressure and a risk score about his health. Furthermore, the relative OWL ontology is presented in Figure 2 describing the semantics of the $RiskAssesment$ element.

The Fog infrastructure includes LTE-A [27]–[29] Macrocell and Femtocells, IEEE 802.16 WiMAX [30] Macrocells and Femtocells and IEEE 802.11p WAVE [31], [32] RSUs, while at the same time the Cloud infrastructure includes a set of Virtual Machines (VMs) implementing a central repository for HL7 medical data. Each VM of the Cloud hosts a part of the HL7 medical data that exist in the aforementioned central repository. Finally, a Software Defined Network (SDN) controller is also included in the topology providing centralized control of the entire system.

TABLE I: Sample of the HL7 RiskAssesment element.

```
<?xml version="1.0" encoding="UTF-8"?>
<RiskAssessment xmlns="http://hl7.org/fhir"><id value="cardiac"/>
  <text><div xmlns="http://www.w3.org/1999/xhtml"><table>
        <th><td colspan="2"> <h1> General Data:</h1> </td> </th>
          <tr>
            <td><strong> Age:</strong> </td>
            <td> 32 </td>
          </tr>
          <tr>
            <td> <strong> Gender:</strong> </td>
            <td> Female </td>
          </tr>
          <th>
            <td colspan="2"> <h1> Clinical Data:</h1> </td>
          </th>
          <tr>
            <td> <strong> Total Cholesterol:</strong> </td>
            <td> 247 mg/dL </td>
          </tr>
          <tr>
            <td> <strong> HDL Cholesterol:</strong> </td>
            <td> 51 mg/dL </td>
          </tr>
          <tr>
            <td> <strong> Smoker:</strong> </td>
            <td> Yes</td>
          </tr>
          <tr>
            <td> <strong> Systolic Blood Pressure:</strong> </td>
            <td> 110 mm/Hg</td>
          </tr>
          <tr>
            <td valign="top"> <b> Risk Score:</b> </td>
            <td> 4\%<br/>
                   Means 4 of 100 people with this level of risk
                   will have a heart attack in the next 10 years.</td>
          </tr>
        </table> </div> </text>
</RiskAssessment>
```

The proposed scheme supports three main processes, which are mentioned as the data upload process, the data update

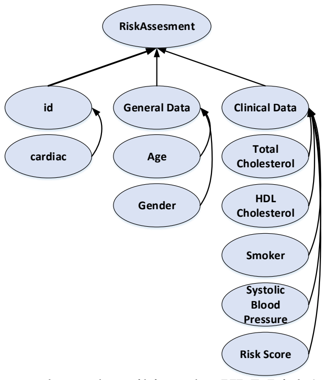

Fig. 2: The OWL ontology describing the HL7 RiskAssesment element.

process and the data request process. Each process is provided to on-board patients.

Figure 3 presents the data upload and the data update processes. Specifically, the on-board patient collects medical data about his health status using IoT equipment. Subsequently, the IoT equipment interacts with the AVD which serves the specific patient and transmits the collected data. Then, the AVD interacts with its HL7 medical data repository and checks if medical data about the patient already exist. If there are no medical data to the repository, the AVD creates a new health record [33] about the patient and stores the collected data. In particular, the AVD adds the received data to the HL7 repository considering the data structure and semantics described in the OWL ontology. On the contrary, if medical data about the patient already exist, the update process is executed in order the existing data to be updated with the new information. Furthermore, the AVD transmits the collected data to a Fog infrastructure which temporarily caches them. Also, the Fog forwards the medical data to a Cloud infrastructure which maintains a central HL7 repository. Thus, the medical staff can access remotely the information to assist in patient care, by communicating either with the Fog or the Cloud infrastructures depending on their geographical locations or the capabilities of their specific equipment.

Correspondingly, during the data request process which is presented in figure 4, the on-board patient interacts with the corresponding AVD and requests specific medical data. In this case, the AVD retrieves the requested data from its HL7 repository, considering the structure and the semantics of the stored data as they are described in the OWL ontology.

It should also be noted, that in both data upload, data update and data request processes, the required user authentication is performed, since the exchanged information is quietly sensitive. However, in this paper we do not deepen on security issues as we focus on the medical data manipulation considering the OWL ontology as well as on the underlying 5G network architecture.

IV. Case Study

This section presents an example of the functionality of the proposed scheme. Firstly, an on-board patient (or on-board medical staff) uses IoT devices to collect data about his health status. Subsequently, the IoT devices transmit the collected data to the corresponding AVD. Thereafter, the medical data are added to the local HL7 repository that exists to the AVD. To accomplish this functionality, the AVD considers the medical data structure and semantics described in the relative OWL ontology. Subsequently, the collected data are transmitted to the Fog infrastructure. The Fog caches the medical information and, then, it transmits the data to the Cloud.

Then, the on-board patient uses the OBU of the vehicle to request the medical data from the corresponding AVD. In this case, the total time required in order the OBU to retrieve the requested data is equal to $1.13ms$ since the required data are already available locally. Furthermore, remote medical staff can obtain access to the medical information of the considered patient. Indicatively, in this case study an authenticated remote user requests the medical data of the patient from the Cloud and, subsequently, the medical information is transmitted to the remote user. It should be noted that the total time required in order the remote user to receive the requested data is equal to $21,33ms$. Also, another authenticated remote user requests the medical data from the Fog. In this case, the Fog has already cached the requested data. Thus, it immediately transmits the data to the aforementioned remote user, while the total time required in order the user to receive the requested data is equal to $5,12ms$. As it could be observed, the on-board patient that interacts with the AVD, immediately receives the requested data with the least possible delay, while the required time in the case of interaction with the Fog is less than the one observed when a user requested to receive medical data from the Cloud.

Finally, the on-board IoT devices of the vehicle transmits an updated value for the $SystolicBloodPressure$ information to the AVD, which is also forwarded to the Fog and the Cloud infrastructures. Thus, the HL7 medical data about the specific on-board patient are updated to both AVD, Fog and Cloud infrastructures. Figure 5 presents the update performed to the user's medical data as it is displayed to the OBU of the vehicle. As illustrated, the corresponding value is updated from $110mm/Hg$ to $112mm/Hg$.

V. Evaluation of the Proposed Scheme

In this section the design of the proposed scheme is compared with the HMS [13], the Fog-MDM [15], the PHR [16], the OAIS [18] and the MIME [21] schemes. Firstly, table II compares the considered schemes in terms of the Information and Communication Technology (ICT) infrastructure that each scheme supports, as well as in terms of the interoperability capabilities of each scheme. As it could be observed, the proposed scheme is the only one that satisfies all the requirements.

TABLE II: Comparison between the considered schemes.

Scheme	Cloud	Fog	Optimized support for Vehicular Users	Use of Interoperable Standards for Data Manipulation
HMS [13]	✓	✓		
Fog-MDM [15]	✓	✓		
PHR [16]	✓			✓
OAIS [18]	✓			✓
MIME [21]	✓	✓		✓
Proposed	✓	✓	✓	✓

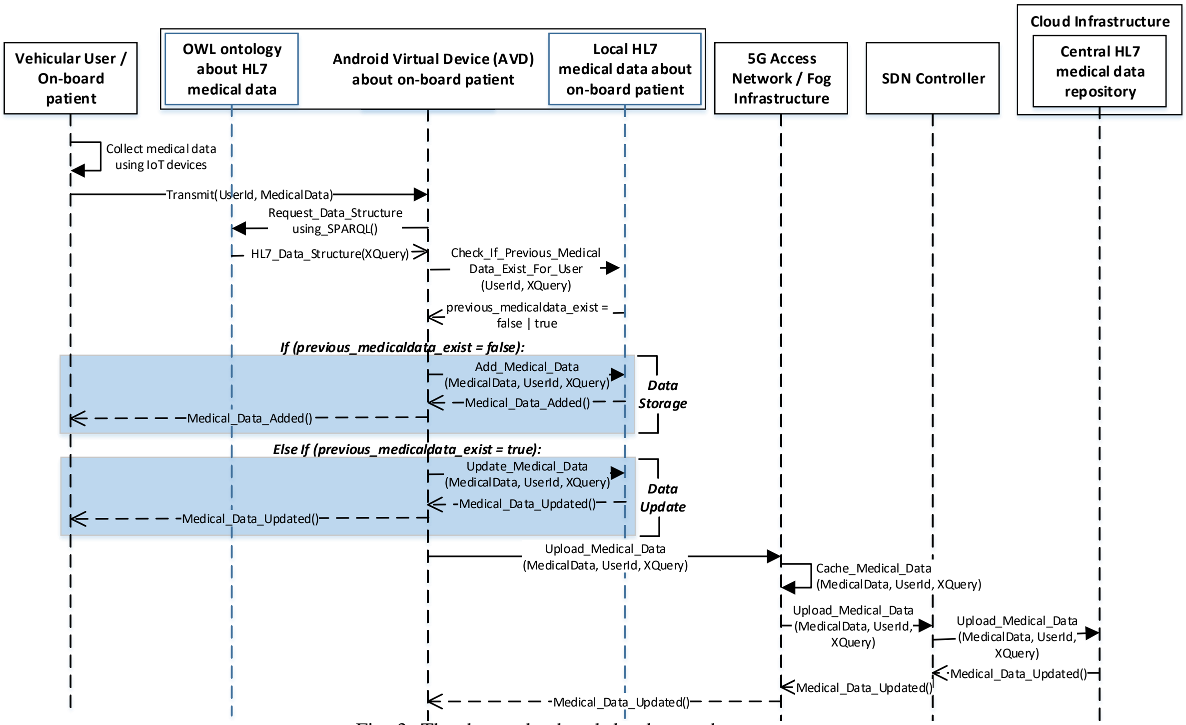

Fig. 3: The data upload and the data update processes.

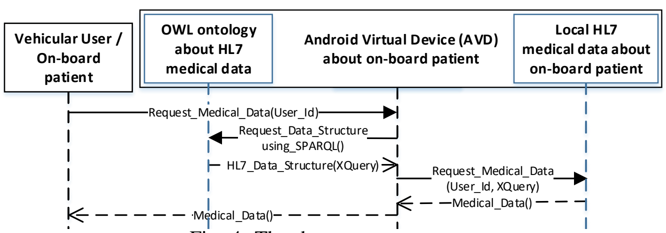

Fig. 4: The data request process.

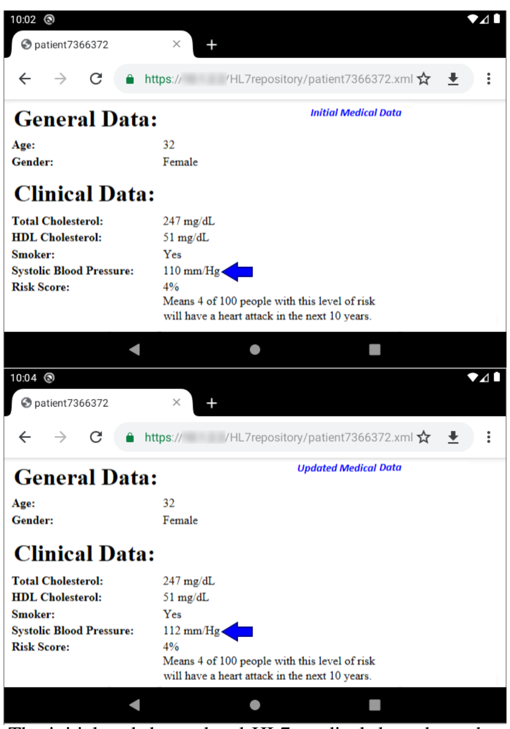

Fig. 5: The initial and the updated HL7 medical data about the patient.

Furthermore, the aforementioned schemes are compared considering the delay observed for the retrieval of the collected medical data (Figure 6) about the on-board patient. Specifically, the question here is where the medical data are spatially hosted, since the longer the distance between the on-board patient and the data-hosting infrastructure, the higher the retrieval delays are observed. In general, Cloud computing can offer more computational and storage resources than Fog and AVDs. However, Cloud infrastructures are usually implemented in large datacenters, away from the access network. Thus, vehicular users are accessing the Cloud resources through backbone network infrastructures. Consequently, increased communication delays arise, decreasing the observed QoS of the demanding medical services. On the contrary, Fog computing can offer enough computational and storage resources, while at the same time it is deployed to the access network infrastructure, decreasing the communication delays, in comparison with Cloud computing. Furthermore, AVDs can manipulate the medical information using communication and storage resources that are available locally in each vehicle's OBU. Thus, in cases where AVDs are used for the medical data manipulation, the retrieval delays are minimized. Also, if necessary, the collected medical data can be transmitted for storage to Fog or Cloud infrastructures at a later time.

VI. Conclusion

This paper proposes a Storage as a Service (STaaS) scheme for the manipulation of medical data created from vehicular users. The data are produced using vehicular equipment such as IoT devices and sensors. The manipulation of the data is performed by applying the Health Level 7 (HL7) standard in

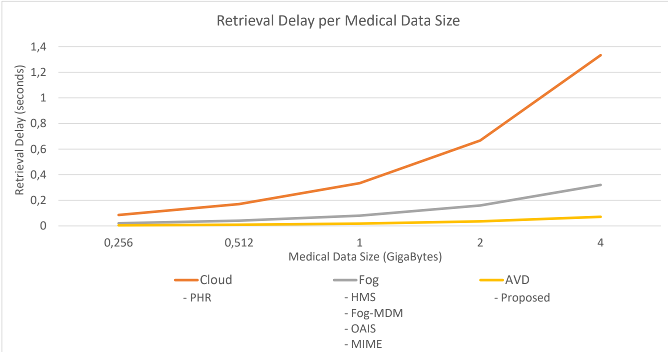

Fig. 6: The retrieval delay per medical data size observed in each scheme.

order the interoperability of the proposed scheme with third-party systems to be ensured. Furthermore, the data access is performed considering the relative ontological descriptions which are created using the Web Ontology Language (OWL). Using the proposed scheme, the medical staff is able to remotely monitor the health status of vehicular users in order to provide medical support in critical cases. Performance evaluation showed that the proposed scheme outperforms existing solutions in terms of the transmission delay of the medical data.

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