International Journal of Advanced Smart Convergence Vol.9 No.2 164-172 (2020)
http://dx.doi.org/10.7236/IJASC.2020.9.2.164

IJASC 20-2-19

On-Demand Broadcasting for Healthcare Services using Time-Parameterized Replacing Policy

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Abstract

The interest and importance of the convergence services for healthcare expand more and more as the average life expectancy increases. Convergence of ICT and healthcare technology unfold efficient and quick health services. Recently, healthcare services provide to clients with apps over web. On-demand wireless data broadcast supports any number of clients to access their desired data items dynamically by responding the needs for data items from the clients. In this paper, we propose an on-demand system to broadcast FHIR bundles for efficient healthcare services. We use time-parameterized replacing policy for renewing the bundle items on the wireless broadcast channel. The policy lets the on-demand broadcasting dynamic by controlling the time duration for the bundles to reside over the wireless channel. With simulation studies using an implemented testbed, we evaluate the performances of the proposed system in access time and tuning time. For evaluation, we compare the time-parameterized replacing policy of the proposed system with regular-number replacing policy. The proposed time-parameterized replacing policy shows shorter access time than the regular-number replacing policy because the policy responds more actively and dynamically to the change of the needs of the clients for FHIR bundles.

Key words: *Wireless Data Broadcast System, On-demand, Replacing Policy, Healthcare Service.*

1. Introduction

As the expectancy of the average life of people increases, the interest to the healthcare and well-being services grows. As a result, the volume of the industry related to health services increases in size. Convergence between ICT and various fields of industry enables to expand the scope of the convenience by making new services for life [1]. Especially, the convergence of ICT and healthcare technology unfolds efficient and quick health services such as telemedicine. Also, the healthcare services based on ICT can be an alternative for controlling efficiently the pandemic disease by quick and correct treatments [2, 3].

In order for the ICT healthcare services to be allowed, the medical information of each person has to be managed efficiently. The information has to be allowed to be used for preparing other services. Also, the personal healthcare information has to be structured and well-formed to interoperate between medical centers

Manuscript Received: May. 10, 2020 / Revised: May. 14, 2020 / Accepted: May. 19, 2020
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and ICT corporations. HL7 (Health Level 7) FHIR (Fast Healthcare Interoperability Resources) is a document-based standard for medical information interoperation [4]. FHIR enables to interchange easily medical information by web services in type of bundles, that is consist of resources. Recently, healthcare services provide to clients with app-based services. The clients receive healthcare documents from the medical center and activate and use various health service apps [3]. In ICT-based healthcare services, it is one of the important things to deliver the information to clients in the well-formed documents. FHIR documents in well-formed structure can be an alternative for the services [5].

The healthcare services can be characterized by a mass number of clients try to access their own health information simultaneously. Thus, the server for the healthcare services has to support a great number of clients in the same time. Broadcasting can treat properly the obstacle to have to allow the clients to access their own health information because it can support any number of clients in the same time without burning down [6, 7].

In broadcasting scheme for healthcare information delivery services, the broadcast server put the data items related to healthcare services such as FHIR documents over the wireless channel on the air. Then, the clients access the wireless channel and download their desired data items. Thus, the broadcasting scheme can accommodate any number of clients in the wireless channel. In the broadcasting scheme, however, the server decides data items to be broadcast. This means that the broadcasting scheme cannot respond quickly to the change of the needs of the client to data items [8].

On-demand broadcast is proposed to solve the problem of the broadcasting scheme that cannot treat the needs of clients. In the on-demand broadcasting, the clients send a request of the information about what data items they want to the broadcast server [9]. The server collects the requests from the clients and decides data items to be broadcasting by reflecting the requests from the clients. Thus, On-demand broadcasting system can respond dynamically to the change of the need of the clients [11, 12].

In this paper, we propose an on-demand broadcasting system for healthcare services in order for the clients to access efficiently and quickly their desired data items and for the server to respond dynamically to the change of the needs of the clients. Figure 1. depicts the proposed system. In the system, each client sends a bundle request information (BRI) to the broadcast server, that keeps the information about what FHIR resources it wants. Then, the broadcast server gathers BRIs from the clients and takes FHIR bundles for BRIs through FHIR server and EMR server in medical centers.

In our system, we proposed time-parameterized replacing policy for adopting actively the changes of the needs of the clients. The policy replaces broadcast data items with newly requested data items using the time information on request time and broadcast time.

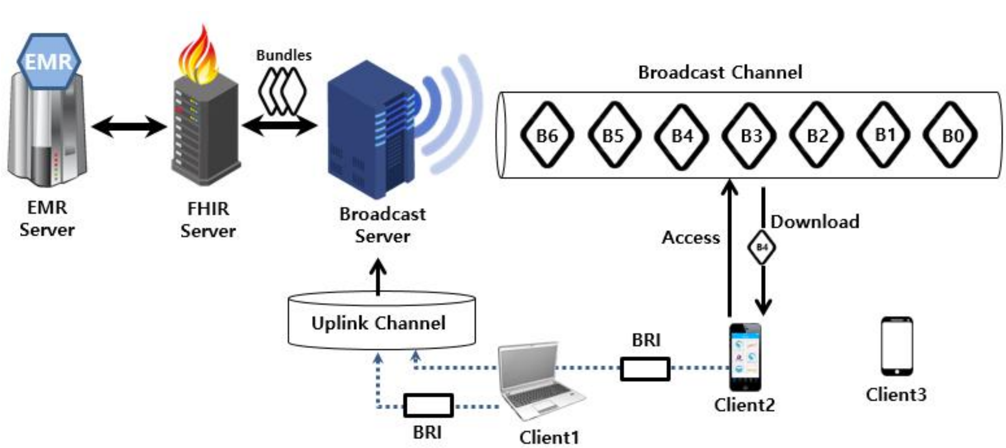

Figure 1. An On-Demand Wireless Data Broadcasting System For FHIR Resources

We describe the proposed system in this paper as follows. In Secion 2, we summarize HL7 FHIR documents as related works. We provide on-demand broadcasting system and time-parameterized replacing policy in Section 3. In Section 4, we simulate and evaluate the performances of the proposed system. Finally, we conclude the paper in Section 5.

2. Related Works

FHIR is a standard for interoperating healthcare resources for various medical and healthcare services. FHIR provides the healthcare information with a document called bundles consisting of several FHIR resources as shown in Figure 2. The figure shows the resources indexes of FHIR. FHIR helps exchange healthcare information by assembling selectively resources according to the needs of the information. FHIR has characteristics as follows: reorganization of bundles according to the needs, easy and quick implementation [5].

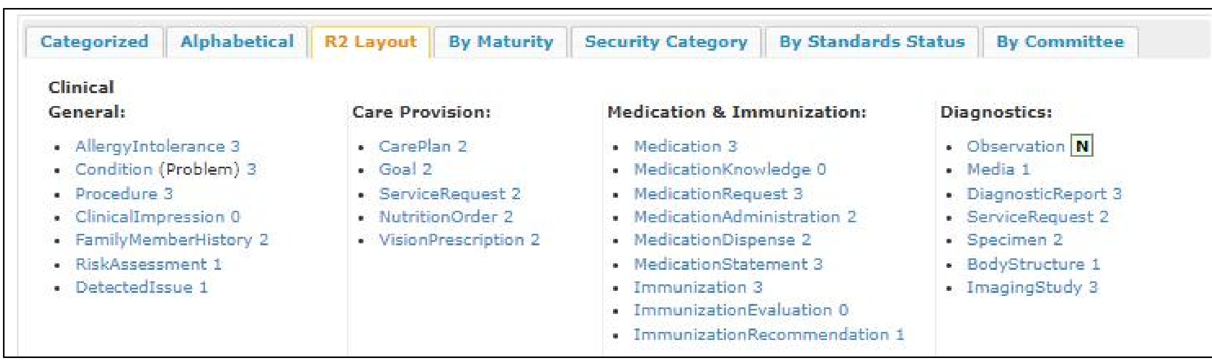

Figure 2. Resource Index of FHIR (http://hl7.org/fhir/resourcelist.html)

Interoperation of healthcare information using FHIR reduces the cost of the healthcare services bacause one module developed in a center can be other service centers.

3. On-demand Broadcasting Scheme for FHIR Resource Bundles

In an on-demand broadcasting system as shown in Figure 1, the broadcast server disseminates N FHIR bundles requested from the clients, that is returned from the FHIR server. The broadcast server replaces periodically the disseminated bundles using BRI (Bundle Request Information) the clients send. Thus, the broadcast server applies the changes of healthcare information of the clients to the wireless channel. The broadcast server provides dynamic broadcast services to the clients by adopting their needs for the healthcare information.

3.1 Broadcast Server

The broadcast server collects BRI through the uplink channel from the clients, an information of resources that the clients try to download from the broadcast channel. BRI is a set of k FHIR resource names that the client try to obtain as a bundle, organized as below:

$$BRI = \{ RES_1, RES_2, \ldots RES_k\} \quad (1)$$

In equation (1), RES_i means a name of FHIR resource that the client requests for downloading from the wireless broadcast channel.

The server requests bundles to the FHIR Server with BRIs from the clients. Then the FHIR server requests healthcare information for bundles to EMR server holding the healthcare information. For the request the EMR returns the healthcare information to FHIR server to organize bundles with the information. The FHIR server organizes bundles with the healthcare information of the clients and provides them to the broadcast server.

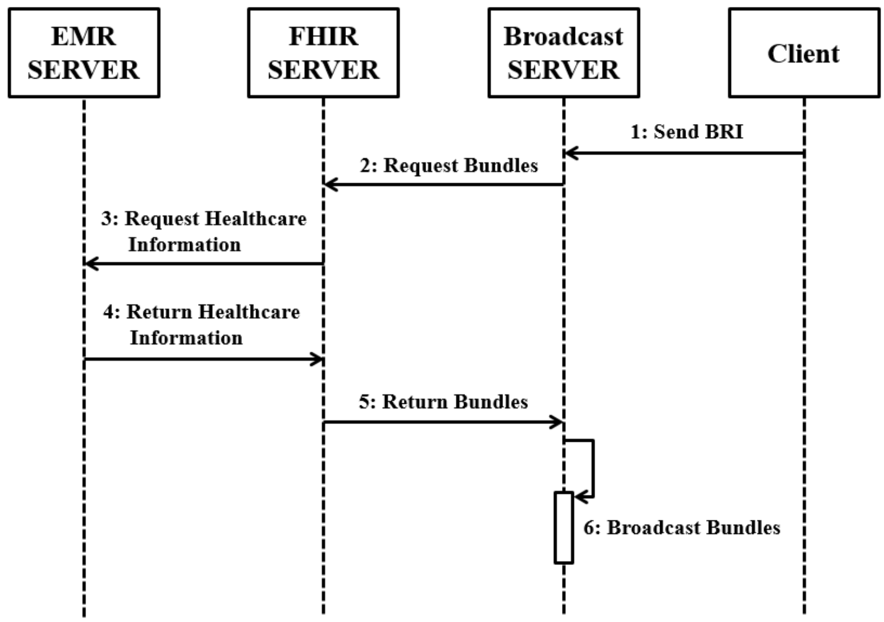

Figure 3. Organizing bundles to be broadcast

Figure 3 shows the procedure for providing bundles to be broadcast with the BRIs from the clients and each process means as belows.

1: A client sends BRI to the broadcast server through the uplink channel.
2: The broadcast server requests a bundle of FHIR resources with BRI from the client to the FHIR server.
3: The FHIR server requests to the EMR server that manages the healthcare information of the client in order to organize the bundle for the BRI.
4: The EMR server searches the healthcare information for the request from the FHIR server and returns to the FHIR server.
5: The FHIR server organizes a bundle with the healthcare information from the EMR server and returns to the broadcast server.
6: The broadcast server disseminates the bundles with the index information over the broadcast channel.

3.2 Replacing Bundles on the Wireless Channel

The broadcast server disseminates bundles over the broadcast channel and periodically replaces the bundles to adopt the changes of the BRI from the clients. The broadcast server uses the time-parameterized replacing policy (TRP) for renewing the bundles on the broadcast channel.

The policy is described as below:

$$T_{org} - T_{in} > \alpha T_{broad} \text{ for bundle } B_i \quad (2)$$

In equation (2), T_{org} means the time when the server estimates whether a bundle is replaced or not. T_{in} is the time the bundle B_i was added and began to disseminate over the channel. The constant α is an integer for deciding the time length for that the bundle is disseminated over the channel. T_{broad} is the time length of broadcast cycle for disseminating the N bundles.

The time-based replacing policy replaces bundles taking long after being broadcast with new bundles. Thus, the policy satisfies the needs of bundles from the clients and enables the clients to download bundles from the broadcast channel that they desire to access. Also, tuning the value of α enables to control the time duration for the bundles to reside over the wireless channel. The low value of α makes the wireless channel to contain more newly disseminated bundles. The high value of α , however, allows the bundles to reside longer on the channel and the clients .

3.3 Organizing the Wireless Broadcast Channel

The broadcast server disseminates the bundles from the FHIR server. For the clients to access energy-efficiently, the server broadcast index information with the bundles in the manner of interleaving [10]. Figure 4 shows the wireless channel structure for on-demand broadcasting. In this paper, we adopt FRI as an indexing scheme that proposed in [13] because this paper focuses on the on-demand broadcasting scheme not on indexing bundles.

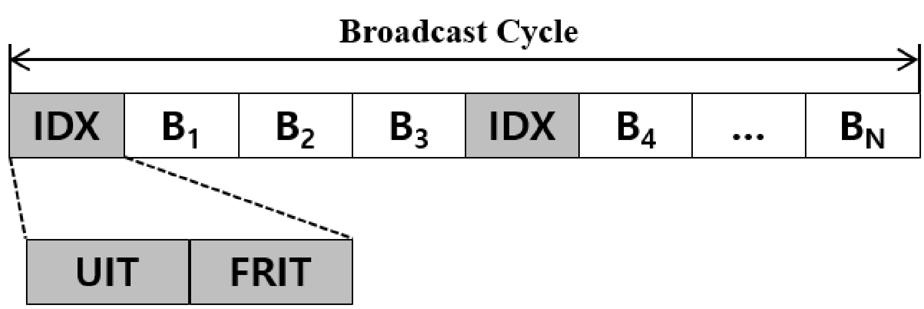

Figure 4. Wireless Channel Structure for On-Demand Broadcasting

In Figure 4, B_i means a bundle of FHIR resources that the clients request to the broadcast server to download. In the figure, IDX means the index information FRI, that holds two kinds of indexing table, UIT (User Indexing Table) and FRIT (FHIR Resource Indexing Table) for the clients to access their desired bundles to download. UIT is a table keeping tuples of the ID of a client and the time information when the bundle the client try to access appears on the wireless channel. With UIT, the clients access efficiently the bundles they desire to download from the channel. FRIT is another indexing table of FRI, that holds time information of the broadcasting time of each resources in a bundle. Using FRIT, the clients access the resources in the bundle they try to download from the wireless channel.

3.4 Searching the Index and Downloading FHIR Resources

In the on-demand broadcasting system, the clients download their desired FHIR resources in the bundle that they request through BRI..

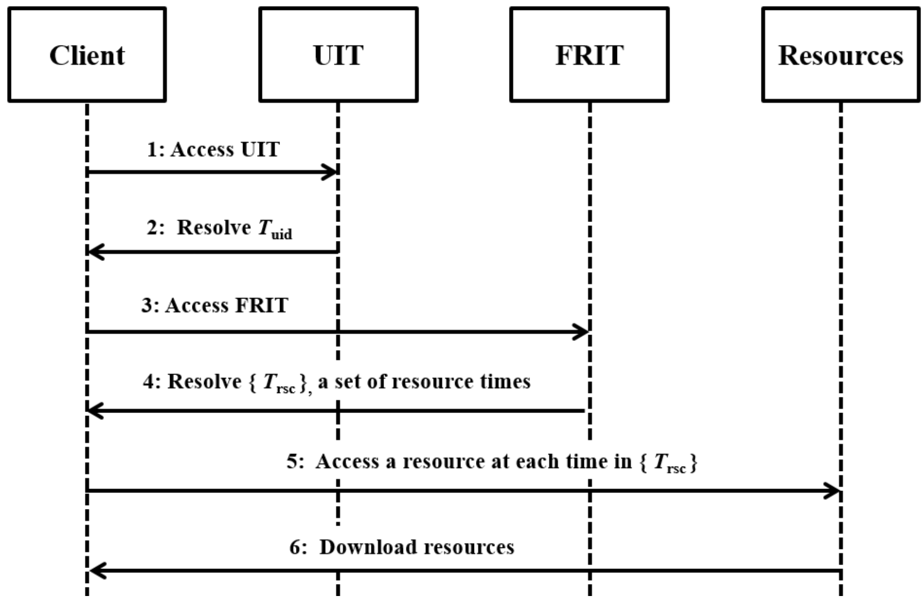

Figure 5. The Sequence Diagram for Downloading FHIR Resources

Figure 5 describes the procedure that a client downloads the resources from the wireless broadcast channel

1: The client accesses UIT on the wireless channel using the time information to UIT contained in a bucket, the smallest logical information unit on the channel.

2: The client searches UIT and resolves the time T_{uid} that means the broadcasting time on the wireless channel for the bundle that it tries to access.

3: The client accesses FRIT on the wireless channel at the time T_{uid} that is resolved with UIT.

4: The client resolves a set of broadcasting times { T_{rsc} } for the FHIR resources it tries to download using FRIT. Here, FRIT holds the broadcasting times of resources in the bundle that is broadcast at the time T_{uid}.

5: The client tunes into the wireless broadcast channel at each time in { T_{rsc} } for accessing the resources it tries to download.

6: The client downloads the FHIR resources after tuning into the channel.

Thus, the clients obtain the broadcasting time information for their desired bundles using the two time tables, UIT and FRIT. That allows the clients to download the bundles energy-efficiently by accessing them selectively with the time information.

4. Performance Evaluation

4.1 Simulation Environments

We implemented the simulation testbed for the proposed on-demand broadcasting system using discrete time simulation package in JAVA. In the testbed, we assume that each client requests to the broadcast server a bundle with 3 FHIR resources in various resources. Each resource is the 4KB and the bundle each client requests has 12 KB in size. Figure 6 shows an example of the FHIR resources in resource type of medication.

```
{
  "resourceType" : "Medication",
  // from Resource: id, meta, implicitRules, and language
  // from DomainResource: text, contained, extension, and modifierExtension
  "identifier" : [{ Identifier }], // Business identifier for this medication
  "code" : { CodeableConcept }, // Codes that identify this medication
  "status" : "<code>", // active | inactive | entered-in-error
  "manufacturer" : { Reference(Organization) }, // Manufacturer of the item
  "form" : { CodeableConcept }, // powder | tablets | capsule +
  "amount" : { Ratio }, // Amount of drug in package
  "ingredient" : [{ // Active or inactive ingredient
    // item[x]: The actual ingredient or content. One of these 2:
    "itemCodeableConcept" : { CodeableConcept },
    "itemReference" : { Reference(Substance|Medication) },
    "isActive" : <boolean>, // Active ingredient indicator
    "strength" : { Ratio } // Quantity of ingredient present
  }],
  "batch" : { // Details about packaged medications
    "lotNumber" : "<string>", // Identifier assigned to batch
    "expirationDate" : "<dateTime>" // When batch will expire
  }
}
```

Figure 6. An Example of FHIR Resources in the type of Medication

The FHIR resource shown in Figure 6 as an example is in the type of medication. The resource contains as attributes identifier, code of the medication, status, manufacturer, form, amount and so on.

The testbed has 1000 clients and each client requests a bundle to the broadcast server with BRI. The broadcast server disseminates N bundles from the bundles the clients request. As the default value, we use N is 700. The broadcast server replaces bundles with newly requested bundles using the time-based replacing policy. The broadcast server keeps the length of the broadcast cycle constant. Also, we use the bucket in size of 512 bytes, that is the logical unit for broadcasting bundles.

We monitor the access time and tuning time of the clients as performance parameters. The access time means how quickly a client access its desired bundle from the wireless channel. The tuning time means how much the client spends the energy during downloading the bundle. We measure the two performance parameters in the number of buckets.

4.2 Experiments

With the testbed, we simulate the on-demand wireless broadcast system in the given parameters mentioned above. We compare the proposed system in the two performance parameters, the access time and tuning time with the on-demand system adopting a regular-number replacing policy (RRP). The regular-number replacing policy means that the broadcast server replaces the same number of bundles in every broadcast cycle. RRP does not consider that how long bundles stay on the wireless channel.

Figure 7 depicts the average access time of the clients by the two replacing policies, TRP and RRP. Here, TRP(k) means TRP with k as the time parameter. The figure demonstrates that TRP lets the clients access more quickly the bundles they request to the broadcast server than RRP. The access time by TRP(2) is shorter than that by TRP(5). That results from that the broadcast server replaces more frequently with smaller time parameter for TRP than larger value of time parameter. With smaller time parameter for TRP, the wireless channel is renewed with newly requested bundles from the clients.

Figure 8 shows the average tuning time of clients by the two replacing policies. The figure shows the tuning times by TRP and RRP are almost same. That results from that the tuning time of the clients depends on the indexing scheme for bundles disseminated over the wireless channel. The two replacing policies, TRP and RRP, uses the same indexing scheme for the simulation. That is because we focus on the effect that how much the replacing policy causes the access time.

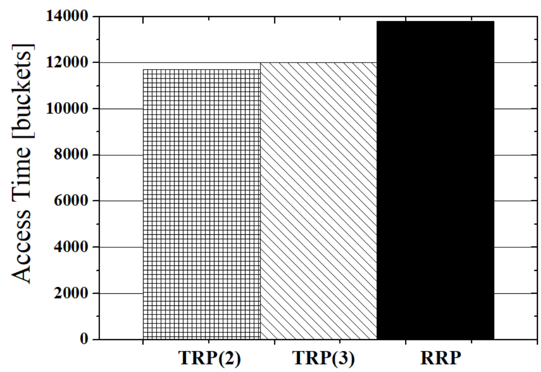

Figure 7. Comparison of the Access Time

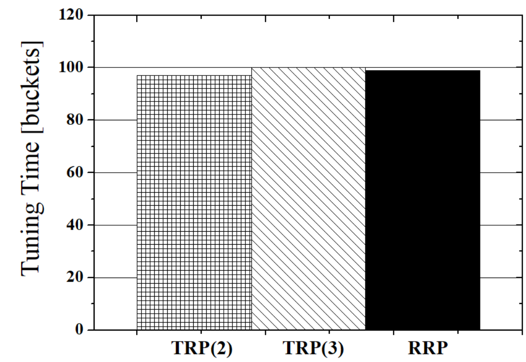

Figure 8. Comparison of the Access Time

5. Conclusion

In this paper, we proposed the on-demand broadcasting system for FHIR resource bundles targeting efficient healthcare services in the environment that the interest of healthcare services increases consistently with the expectancy of the life lengthening. In the proposed system, the clients requests bundles of FHIR resources with BRI, then the broadcast the bundles the over wireless broadcast channel. The on-demand system needs the quick response to the requests from the clients. In order to meet the need, we introduced the time-parameterized replacing policy that is for renewing efficiently the FHIR bundle on the wireless broadcast channel. Using the policy, we controls the time duration that the FHIR bundles are disseminated over the wireless channel. Also, the policy allows the on-demand broadcasting system responds more actively and dynamically to the change of the needs of the clients for FHIR bundles. We demonstrate the performance of the proposed policy and the system with the access time and the tuning time of the clients by simulation studies. The evaluation shows the proposed replacing policy outperforms the other replacing policy. As the future work, we research the dynamic scheduling scheme for rearranging bundles on the wireless channel to improve the access time of the clients.

Acknowledgement

This research was supported by Basic Science Research Program through the National Research Foundation of Korea (NRF) funded by the Ministry of Education (2018R1D1A1A09057077)

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