Healthcare Information Network Testbed through Content-Centric Network: A Prototype

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Abstract: Healthcare and hospital are the most complex service systems. There are three often conflicting dimensions including: clinical data (patient record, medical data), operational, and Financial. Recently we worked on a data processing system for managing and exchanging patient records that are distributed in various hospitals under the medical cloud via the dedicated bandwidth network, namely, the dynamics circuit network (DCN). However, this approach needs the specific devices for supporting the dedicated resources. Currently, a new approach for network that enables the communication to happen by the means of content instead the location called the Content-Centric networking (CCN), which seems to be more beneficial as it reduces congestion and latency and supports emerging applications on mobile and wireless facilities. This paper is a proof of concept in designing a model of Medical network under the Information Centric Network, which is an ad-hoc, flexible, reliable, and simple to use under the Content-Centric concept. Advantages for the e-community as a result of this network will be discussed.

Keywords: Information-Centric Network; Content-Centric Network; Named Data network; Future Internet.

1. Introduction

Healthcare and hospital are the most complex service systems. There are three often conflicting dimensions including: clinical data (patient record, medical data), operational, and Financial. MEDINET is a consortium and testbed of medical academics and healthcare partnership between Ministry of Education and Ministry of Public Health, which establish to
improve and integrate processes in complex environment. The previous work [8], we work on a data processing for building the system of managing and exchanging patient records that are distributed in various hospitals, which HL7 [2] is designed to support a central patient care system. Moreover, we develop a network infrastructure to communicate among the hospitals under the Dynamic Circuit Network - DCN [3], which support for the huge of data. However, this approach needs the specific devices for supporting a dedicated bandwidth and difficult for a mobility services. Dynamic circuit networks (DCN) were pioneered by the Internet2 advanced networking consortium. It can provide on-demand bandwidth network, which suitable for bulk data transfer such as image or multimedia data. This system transfers data via interface layer, which including Virtual Label Switch router (VLSR) and Inter-domain controller (IDC). The dynamic circuit network (DCN) is working as an infrastructure.

Nowadays, a new approach for networking that enables the communication to implement by the means of content instead the location called the Content-Centric networking (CCN) [1], [4], [9], [10], which is more benefit such as reduces the congestion and latency, supports the new and emerging applications on mobile and wireless facilities. Many research project during the recently year going under the information centric network such as PSIRP [7], CCNx [6], and NDN [5].

In this study, the new model of Medical network was proposed under the Information Centric Network paradigm, an implementation of content-centric system leveraging the advantages provided by CCNx [6]. The objective of this paper is a proof of concept in designing a model of Medical network under the Information-Centric Network and point for benefit of CCN affected the communities of healthcare services.

2. Backgrounds and Methodology

Healthcare records are distributed in various locations, as each Healthcare Organization keeps its own files, which records on each item same as a hierarchy chart structure. However, the patient data are kept in different locations and/or by various hospitals. In an emergency case, a patient needs some help on the other medical center that did not has his/her records, and some case need to integrate a specialist from the other hospitals for diagnosis as shown in Figure 1.
Figure 1. A sample integrated of healthcare information exchanging.

The medical data that pass through the network are not a tiny of bytes but a huge of bytes; it has to send for diagnosis. Even the dedicated bandwidth mechanism is provided more bandwidth for transmission but the IP networking will drop the performance of data transmission when more concurrently usage occurred. The DCN is provided layer-2 network infrastructure in specific path at a time, all applications are run on the dedicated path as well. In case of concurrent data usage the bandwidth is shared for everyone. Bulk data transfer performance is important to download the large files of healthcare services, which is dropped during transmission on sharing network. However, we have the new approach using the content oriented rather than the connection oriented called Content-Centric network (CCN). That is intended to achieve the contents sharing which construct by name, based on concept of what rather than where. The content-centric networking uses a practical cache at each level of the network to decrease the transmission traffic [10].

2.1. Information hierarchy structure

Healthcare records are distributed in various locations. Each the Healthcare Organization keeps its own files depend on data domain. Normally, a general structure of information usually keep into the hierarchical chart structure, that is easy to search and suitable for functionality.

Figure 2 showed a sample of information hierarchy, each medical unit kept the data in its own storage in various formats (e.g., DICOM, HL7 etc.), which interoperated with the other units, the application must be developed in the service mechanism for providing the appropriate data. From the previous work, all of the application worked on the medical cloud, over IP networking and determined service site by domain name system.
Figure 2. Sample a hierarchy Information and path notation.

The data can discover by path notation that is easy to understand and reference as shown in Figure 2., instead of accessing data by application service, hosts or users communicate to the data by requesting through named of content.

2.2. Content-Centric networking Architecture

The NDN project [5] is one of the four projects, funded by NSF (National Science Foundation). Named data network (NDN) or content-centric networking (CCN) is an alternative approach to the data approach on the network rather than the location approach. The content-centric networking uses a practical cache at each level of the network to decrease the transmission traffic, and also increase the speed of response. A sample of CCN network topology shown in Figure 3 (a, b), which is introduced the model of content-centric network.
Every CCN router has three major components: the first is the content storage, the second is the pending interest table (PIT) and the last component is the forwarding information base (FIB). For example, a user may request /medical/hospital/division/domain-A/patient-1/xray-yyyy-mm-dd.dcm. A router remembers the interface from which the request comes in, and then forwards the request in term of interest packet (stored in PIT) by looking up the name of data in its FIB with the longest matching approach. Once the interest data reaches a node that has the requested data, a data packet will return to the requester both the name and content. Each CCN routers, that the content pass through, will keep the path’s name and data for some period of time. In case of multiple interested messages that requests for the same data, only the first interested message is sent to the target. The router stores the interested message into the PIT just only one record per each interested and updates the interface information of requester for sending the data back. When the data packet arrives, the router finds the matching PIT entry and forwards the data through all interfaces list that related to the contents, and caches the data in the content storage. In CCN, security is built into data itself. The data packet is sent with name and content of data together with a signature by the producer’s key.

2.2.1 Designing Architecture

In this paper, there are two important things to be concern; the first thing is the name convention, which assigns a unique name for each of data. The last thing is the name discovery service, which the requester needs to get a path of content name and send it in term of interested message into the CCN network by the name convention.

2.2.2 Name Convention

The data path of the information hierarchy (Figure 2) can be set as the content name, which unique to reference and easy to manage by the administrator.

ccnx://[group-name]/[hospital]/[division]/[domain]/[personal-id]/[data]

In this case, group of work was combined into the name of content for classification and ignoring any interest message that is not in the group.

2.2.3 Name Discovery

Based on the name convention referencing, each provider who wants to share the data on the CCN networks has the own infrastructure and data structure. The data may be change in some day on any hospital in underlying network that is effected to the named of data. However, on the
consumer’s side, the correct data path cannot specify correctly at the first time. The requesters have to discover a path of content by sending the required name to the discovery node.

Figure 4. A prototype of discovery node topology of CCN.

The name of path on each hospital for discovery should be explicit for another requestor. The pattern of discovery path named show below.

\[ \text{ccnx:[group-name]/[hospital]/[discovery]/[requested data]} \]

The prototype of discovery node topology is showed in Figure 4. The discovery node has a list of content name that published on the underlying node. The full path of content name that published on underlying network will return when the requester send interested message for discovery. This model separates the layer of storage structure from the name of content. Each hospital can modify and revise the path of data without effect to the requester, once the requestor needs the patient data, they will send request to the discovery node then the discovery node will return the correct path to the requestor. However, this model needs a service module that waits for serving the discovery request and service module to update the list of content name, which is published on the underlying network. The detail of algorithm to get the contents is showed in Figure 5.
2.2.4 Prototyping of CCN network

In this section, a proposed prototype of CCN network is a simple Hub and Spoke model architecture. The CCN router splits into sub-network and public-network. Figure 6 showed the concept of our prototype. Each hospital has sub-router and discovery node for communication inside sub-area, and across all sub-areas via core router. However, it should not have the only one core router because of the single point of failure problem.

3. Experimental and Results

The network testbed uses CCNx to evaluate the connection of designing concept architecture. The diagram of experiment is shown in Figure 6. Each node is a CCN-node running the “ccnd” daemon process. The “ccnchat” tool command used to test a connection among end-nodes and uses “ccnputfile/ccngetfile” to evaluate a data transmission.
3.1. Testing network topology

The testbed experiment consists of the five personal computers based on virtualization technology to simulate a CCN network using the CCNx software package on local area network.

Figure 7. CCN network topology for experimental testbed

The experimental network is shown in Figure 7. The network is split into 2 levels. The first level is the zone of sub-network that all nodes are able to communicate together without CCN-Core (C) switch. The second level is the zone of public network, all nodes can not connect directly, if some node in sub-network needs to connect to client on the other zone, the packet will forward to CCN-Core (C) for switching to another. For example of chat system, Client no.2 needs to connect to Client no.3 for talking about something (i.e., Client no.2 will initiate a topic name like this “/medical/discuss/case-01” and then Client no.3 can talk to Client no.2 by running
chat program with the same topic name, the packet will forward to the target node follow by the specific path. (2 $\leftrightarrow$ B $\leftrightarrow$ C $\leftrightarrow$ A $\leftrightarrow$ 3))

3.2. Communication experimental scenario

All testing are split into 2 scenarios, the first is the communication on sub-network and the last one is the communication on public network. The prefix of all communication is defined by “medical”. The interested message is not prefixed by “medical” should not communicate to another nodes. All testing use general utilities of CCNx package, such as “ccnchat” for testing a connection among the nodes and “ccngetfile/ccnputfile” for testing a data transmission between producers and consumers. The result is shown in Table 1.

<table>
<thead>
<tr>
<th>No.</th>
<th>Connection Testing Result</th>
<th>Expected</th>
<th>Testing Result</th>
</tr>
</thead>
</table>
| 1   | Comunication among nodes in sub network (1 $\leftrightarrow$ B $\leftrightarrow$ 2)  
- With ‘medical” prefix  
- Without “medical” prefix | Yes, No  | Yes, No        |
| 2   | Comunication among nodes through public network (  
1 $\leftrightarrow$ B $\leftrightarrow$ C $\leftrightarrow$ A $\leftrightarrow$ 3, 1,2 $\leftrightarrow$ B $\leftrightarrow$ C $\leftrightarrow$ A $\leftrightarrow$ 3 )  
- With ‘medical” prefix  
- Without “medical” prefix | Yes, No  | Yes, No        |

In case of the data transmission, the experiment split into two scenarios. The first scenario is focused on the trend of transmission time against the number of CCN router. The last scenario is focused on the transmission time in concurrently usage. The data in various sizes send through the CCN network. Thus, the testing is just an observation in the trend of the data transmission time compared with the number of CCN router on the network. The result of testing is shown in Figure 8 (a). In the figure 8 (b), we focus on the concurrently usage, the different size of data sent through the CCN network while the same of data sent through the IP network via file transfer protocol (FTP). The transmission time from the both of them are compared together. The CCN is outperform when compares with the FTP in concurrently usage.
Figure 8. (a) Transmission time against the number of nodes, (b) Transmission time in concurrently usage

The graph above shows a transmission time on average of all testing that run in 10 times. The experimental result in figure 8 (a) showed the number of router on the network does not significantly affect the data transmission. However, this evaluation does not focus on the performance, just a proof of concept of the communication in healthcare services on CCN networking only. All components run on Linux OS over the testbed in local area network.

3.3. Healthcare data services over the network

Due to the recently work about the Medical Cloud over Dynamic circuit Network – DCN, the implementation processes are too complicated [3][8]. The operations need many communities to complete the requirements and slightly low level of network layer for configuration. On the other hand, the CCN is stand on higher layer of networking, less time consume to implement and easy to configuration [6]. The DCN is layer-2 networking with overlay scenario and the CCN is stand on the application layer. Thus, the CCN and DCN can work together but the implementation too complicated. The CCN is easier than DCN in point of implementation. However, at the same bandwidth both normal network and dedicated bandwidth network via DCN, the CCN is outperform and suitable for transferring the data of healthcare information services. From the comparison of data transmission of healthcare data services on the network between CCN and DCN, the FTP utility uses for transmission the data via DCN and ccncgetfile/ccnputfile utilities use for transmission the data via CCN, the result is shown in Figure 8 (b). These results are similar to the bulk data transfer via TCP in [10] which content-centric network is better than IP networking in simultaneous scenario.
4. Conclusions

A content-centric network concept works well with the prototype of healthcare information service. A distributed location and multiple site accessibility of data in healthcare services are supported through the CCN infrastructure. In this study, the proposed model is a proof of concept in CCN network for healthcare information services based on information-centric network model that is suitable to implement and less consuming of time to develop the system. However, the testing scenario of this study is working on the data from test environment and not yet evaluates gains the performance, therefore the effect of the number of node and topology should be more investigate in the future.

Moreover, in the view of benefits of a system to the user that consists of the system administrator including a medical staffs and patients that the administrator can manage the system with less learning curve. The documents are eased to classify in the standard formats (e.g., HL7, DICOM, etc.). It could be classified into specific categories for easy accessible. The medical staffs can use the information from their organization and from other sources more quickly. And the collaboration of healthcare services has more variety. Finally, patients can receive the best of services.

References


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