An Efficient Content Delivery Framework for SDN Based LTE Network

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ABSTRACT

As the use of smart devices, such as smart phone, smart pad, etc, increases, the bandwidth for downloading a content also increases in the network. Thusly, the widespread use of Long Term Evolution (LTE) devices make further research necessary into the fields related to managing network and controlling content delivery efficiently in the mobile environment.

In this paper, we proposed the framework based Software Defined Networking (SDN) to support content delivery, network management and network control in LTE. We attach functions of Forwarding Engine and SDN switch into network entities such as evolved Node B (eNB), Service-Gateway (S-GW) and Packet data Gateway (P-GW) to provide efficient content delivery and network management. Then we attach a function of SDN controller into Mobility Management Entity (MME). Via our proposed framework, it is also possible to support a detour path in the middle of GTP tunnel. Via simulation result, we prove our proposed scheme can reduce total content delivery time.

Categories and Subject Descriptors

C.2.1 [Network Architecture and Design]: Network communications

General Terms

Management, Performance

Keywords

Long Term Evolution (LTE), Content Centric Networking (CCN), Software Defined Networking (SDN), Content Delivery.

1. INTRODUCTION

Recently many people use various popular content services such as movie, music streaming service, application download service etc. Almost all of network bandwidth is allocated for content download service. The use of Long Term Evolution (LTE) [1] based devices like smart phone and tablet PC is accelerating this phenomenon. For the content delivery, the research of content centric networking has been progressing steadily, such as Content Centric Network (CCN) [2, 3], Named Data Networking (NDN) [4] and Information Centric Networking (ICN) [5]. However, the research of CCN is lacking the service to support content delivery in the mobile environment. For this reason, the research on the content delivery in the mobile environment and management of network efficiently is on the rise out of necessity.

In this paper we proposed a Software Defined Networking (SDN) [6, 7, 8] based LTE framework to provide efficient content delivery services in the mobile environment and to support easy network management. The CCN forwarding engine and SDN switch are attached to the network entities such as evolved Node B (eNB), Service-Gateway (S-GW) and Packet Data Gateway (P-GW) to be able to provide content delivery in the LTE network. In the Mobility Management Entity (MME), we attach SDN controller to manage the network. Also we proposed a new IPv6 extension header to confirm whether outgoing packets are CCN packets or not. The CCN gateway makes a decision to forward the arrived packets to the internet or CCN network. We can prove that a total delivery time is reduced via performance evaluation with our proposed framework.

The remainder of this paper is organized as follows. In section 2, we briefly introduce about Long Term Evolution, Software Defined Networking and Content Centric Network. Then we discuss about the problem statement of current LTE environment. Section 3 introduces our proposed SDN based LTE network framework for supporting efficient content delivery and managing network. For the performance analysis of our framework, we present the evaluated result in section 4 and we explain the conclusion and our next step in section 5.

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2. RELATED WOKRS

2.1 Content Centric Networking (CCN)

To solve current problems of Internet, many researchers propose to keep the current Internet architecture and modify some functional parts to improve the network performance. However, some researchers employ a clean slate approach to solve current problems of Internet. As a result, many future internet researches were born. Content Centric Networking (CCN) is one part of Future Internet research which concerns with sharing data.

In CCN, each CCN router has a forwarding engine. Forwarding engine consists of three components which are Content Store, Pending Interest Table (PIT) and Forwarding Interest Base (FIB). Content Store is a repository which contains requested contents. PIT is the table that stores information of receiving interest packets. FIB is the table which contains information of outgoing interest packets.

Figure 1 shows a basic routing scheme [9] for content centric networking. A basic routing scheme in CCN is described in the following sequences:

(1) The client 1 sends a interest packet to CCN router H. When CCN router H receives client 1's content request, CCN router H checks its content store to find whether the requested content name is in the table or not. If the requested content name is found within content store, CCN router H sends data packet with requested content to client 1. However, if the content name is not in its content store, CCN Router H forwards interest packets to neighboring CCN routers. Via this way, the interest packet finally arrives to the CCN Router A which has the requested content.

(2) CCN router A receives an interest packet from CCN router B and checks its content store. Then CCN router A sends the requested content using reverse path to router H and each CCN router stores the contents into the content cache when it receives the contents. Finally, client 1 receives the requested content from CCN router H.

(3) The client 2 requests same content which is requested by client 1. CCN router I receives an interest packet. However CCN router I doesn't have the requested content in its cache table. In this case, client 2's request message is sent to CCN router D.

(4) When CCN router D receives the interest packet, it sends a data packet including requested content to client 2.

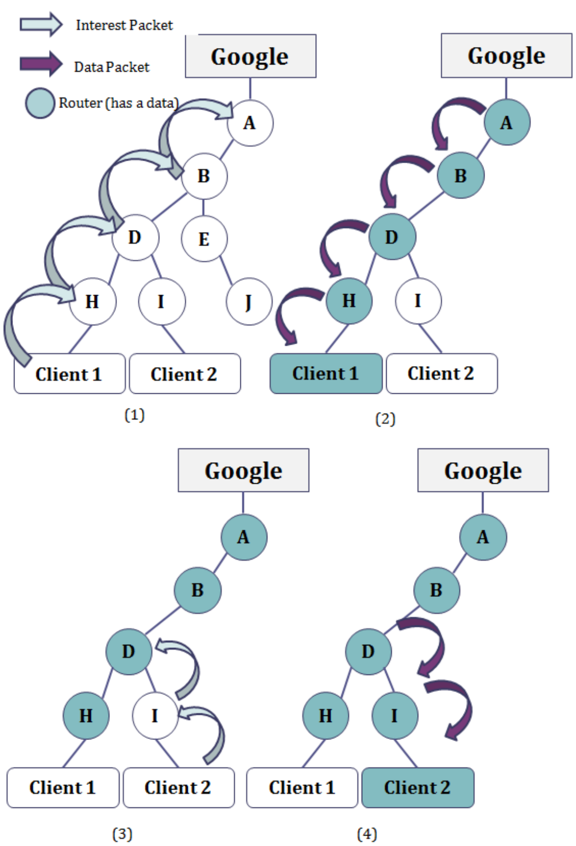

Figure 1. Content Delivery Scheme in Current CCN

2.2 Software Defined Networking (SDN)

SDN (Software Defined Networking) concept is developed to solve recent network problem by UC Berkeley and Stanford University. After development of SDN, we can model networking technology via computer technology.

We can also control and manage network via a software program. Figure 2 is concept of SDN. As shown figure 2, there are two important network components. One is SDN controller. The other one is SDN switch. Each SDN switch contains a flow table. The flow table consists of rules, action and stats. Via flow table, SDN switch can be determined to send packets. If there are no entries of received packet in the flow table, SDN switch sends a packet-in-message to SDN controller. Then SDN controller checks its flow table. If there are some rules (or actions) for received packet in the flow table, SDN controller sends a flow information for requested packet to SDN switch. Then SDN switch updates its flow table and sends a packet with new flow information. If SDN controller does not have flow information in flow table, SDN controller can make new rules (or actions) for the received packet.

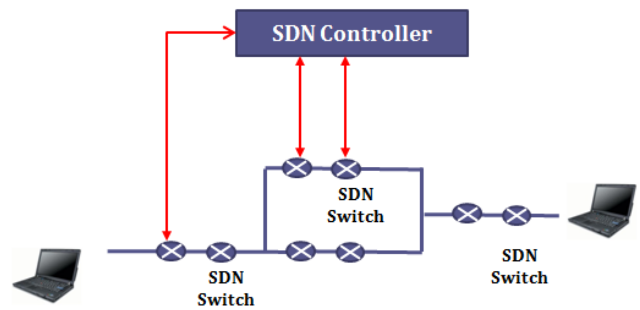

Figure 2. The concept of SDN

2.3 Long Term Evolution (LTE)

LTE which is defined and developed by 3GPP has evolved from mobile communication technology. One of LTE characteristics is all-IP network. And with LTE technology, it is possible to connect IP based network without user location. Via LTE technology it is possible to provide various kinds of multimedia services like voice service, fast mobile web browsing, M2M (Machine-to-Machine) and e-health services. Figure 4 shows the structure of LTE and network Entities. As shown in figure 4, there are 5 important network entities. Detail explanation of each entity is given in table 1.

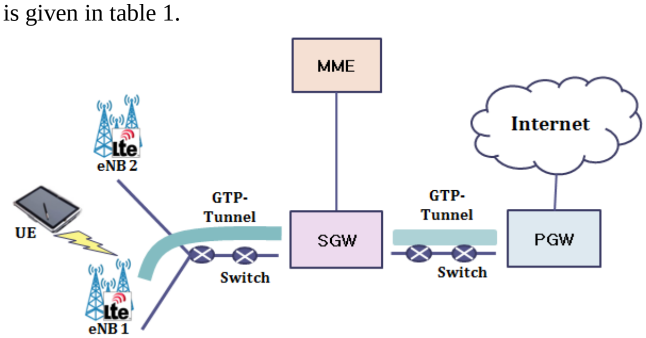

Figure 3. The Structure of LTE

Table 1. The Network Entities in LTE

Entity Name	Explanation
User Equipment (UE)	- As user equipment - Using wireless interface UE can connect with eNB
Evolved Node B (eNB)	- Providing wireless interface to UE - Controlling wireless equipment, load balancing etc.
Mobility Management Entity (MME)	- E-UTRAN control entity - User authentication - Providing a security to UE with NAS signaling
Service Gateway (S-GW)	- Playing a role of anchoring point among the handover between eNBs
Packet Data Gateway (P-GW)	- Providing connectivity between UE and outside packet data network(Internet) - Allocating IP to UE

Except the connection between UE and eNB, all network entities are connected using IP network. Each entity can also communicate with denoted interfaces such as S1 interface and X2 interface [9].

2.4 Problem Statements

In LTE environment, except the connection between eNB and UE, all connections of network entities are connected by IP network. Between eNB and S-GW (or between S-GW and P-GW) network entities are connected with GTP-tunnel which is an IP tunnel. In the GTP-tunnel, there are many switches. If an intermediate switch breaks down or serious network congestion occurs in the GTP-tunnel, it is necessary to create new GTP-tunnel between two network entities. Thus if the network controller is included in the LTE network, it is possible to change a path between two connected network entities. Moreover, this controller can also help to manage UE mobility, in case of handover.

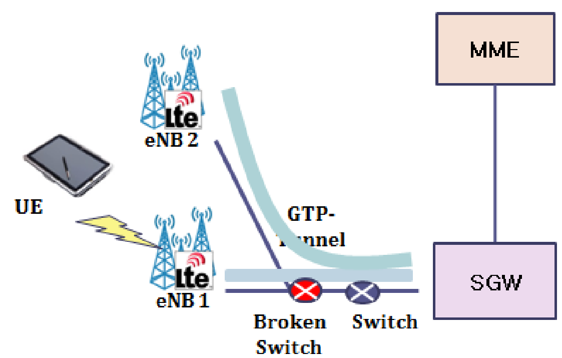

Figure 4. The Problem Statements

Furthermore, many UEs can connect with an eNB. If an UE requests the content in LTE environment, this requested packet is forwarded to P-GW and sent outside of LTE network. However, for multiple requests of the same content by different UEs, the same request packet is repeatedly forwarded to P-GW. If a repository is constructed in the network entities, it can reduce replicas caused by repeated requests of the same content in LTE environment.

3. PROPOSED SCHEME

To support network management and provide content delivery, we proposed SDN based LTE framework. And each LTE network entities are included CCN forwarding engine.

3.1 Overall Architecture

Figure 5 shows the overall architecture of the proposed framework. MME (Mobile Management Entity) includes SDN controller to manage network for content delivery. And all network entities such as eNB, S-Gateway, P-Gateway and switches can play a role of SDN switch to communicate with SDN controller in MME. We propose the CCN Gateway (CCN GW) to confirm whether outgoing packet is CCN packet or not. Also we assumed all IP networks are connected using IPv6. In section 3.5, we discuss detailed operations in proposed scheme using different scenarios.

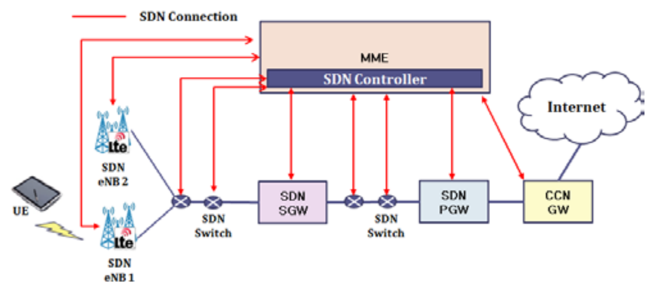

Figure 5. Proposed Overall Architecture

3.2 SDN Controller and SDN Switches

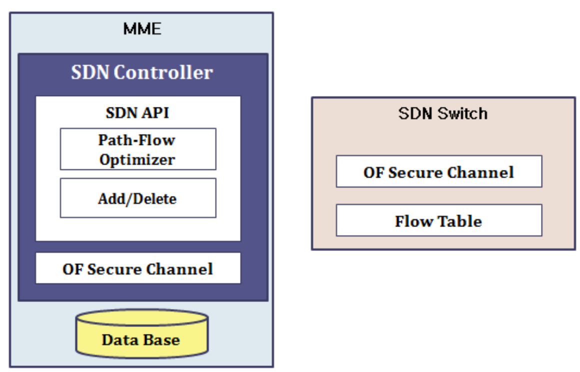

Figure 6. SDN Controller in MME and SDN switch

Figure 6 shows SDN controller in MME and SDN switch. Each LTE network entities have added functions of SDN switch to communicate with SDN controller in MME. If SDN eNB receives messages from UE, SDN eNB checks its flow table entries. There is no information related with received message from UE. SDN eNB sends packet-in-message to MME via secure channel. Then SDN controller checks its flow table to find path information related to received packet from UE and sends the path information to SDN eNB. If there is no path information for receiving packet, SDN controller makes a new path for receiving packet and sends it to the SDN eNB. When SDN eNB receives a path information, eNB updates its flow table and forwards packets using the defined path in the flow table.

3.3 CCN Gateway

CCN gateway is located between P-GW and Internet. The role of CCN gateway is to control outgoing packets. When an outgoing packet from P-GW arrives in CCN gateway, CCN gateway checks whether the received packet is CCN packet or not. CCN packet contains a new IPv6 extension header and its presence is checked to confirm each received packet. If the received packet does not contain CCN Extension header, CCN gateway forwards the packet to Internet. However, if the received packet includes CCN extension header, CCN Gateway decapsulates receiving packet and sends interest packet to CCN router which is connected with CCN gateway. Even though receiving packet includes CCN extension header, if its type is 0x03 (it means type of CCN packet is not designed yet), CCN gateway sends a packet-in-message to SDN controller in MME. We will explain types of CCN packet in the next section in detailed. Furthermore, when CCN gateway receives a data packet from CCN router outside of LTE network, CCN gateway encapsulates receiving data packet to IPv6 packet and attaches IPv6 extension header including the type of CCN packet defined as 0x02 (Data packet).

3.4 IPv6 Extension header for CCN packet

In the previous section, we have already explained the new IPv6 extension header for CCN Packet. CCN extension header is depicted in figure 6. And table 2 shows types of CCN packet. If a type of CCN packet is 0x00, this packet is forwarded to Internet. On other hand, 0x01 is interest packet and 0x02 is defined as data packet. 0x03 is used for the emergency forwarding.

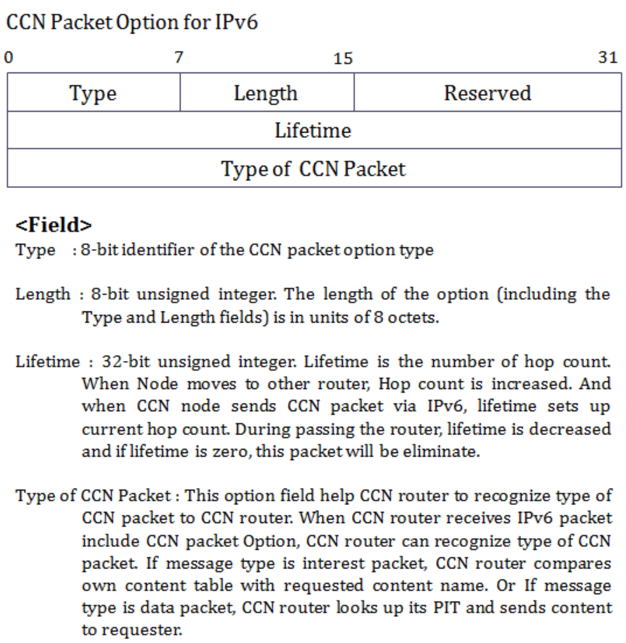

Figure 6. New IPv6 Extension header for CCN packet

Table 2. The Types of CCN Packet

Hexa Code	Explanation
0x00	The packet goes to Internet.
0x01	Interest packet from user
0x02	Data packet from outside CCN router
0x03	For the emergency situation

When network entities receive packet with CCN extension header,

1) If the type of CCN Packet is 0x00, each network entity ignores and sends the received packet to the network.
2) If the type of CCN packet is 0x01, this packet is interest packet from user side.
3) If the type of CCN packet is 0x02, this packet is data packet from outside CCN router.
4) If the type of CCN packet is 0x03, this message is for the emergency situation.

3.5 Operation of Proposed framework

In previous section, we explained our proposed framework. In this section, to introduce the operation of our framework, we describe two scenarios. In the first scenario, we describe how to operate content delivery in our framework. Then we explain the second scenario related to node mobility.

3.5.1 The Operation of Content Delivery

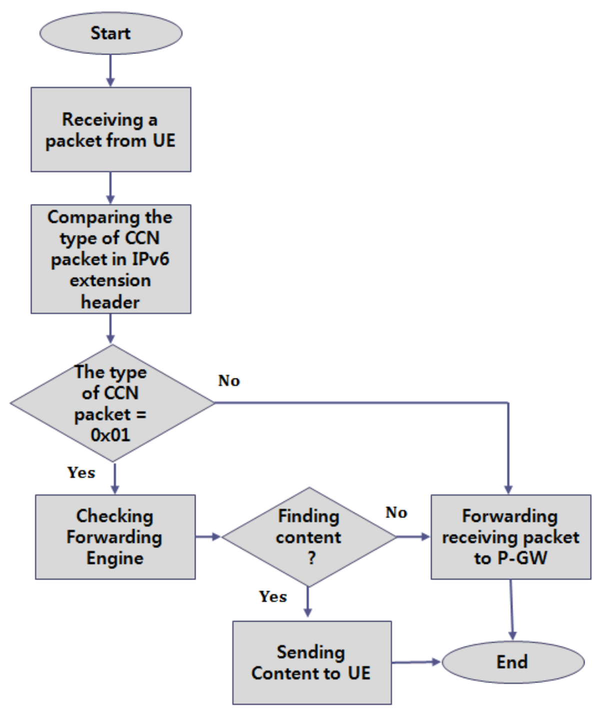

Figure 7. The Content Request Flow Chart of content delivery operation at each network entity

Figure 7 shows the content request flow chart of content delivery operation at every network entity. A content delivery operation in proposed framework is described in the following sequences:

(1) If UE wants to download contents, UE sends an interest packet encapsulated into wireless bearer to SDN eNB

(2) When SDN eNB receives packets from UE, SDN eNB checks whether received packet contains IPv6 Extension header for CCN.

(3) If the type of CCN packet in the extension header is 0x01, network entity decapsulates the received packet and checks its content store in the forwarding table. If the type of CCN packet is not 0x01, network entity forwards the received packet to P-GW.

(4) if SDN eNB finds out requested content in its content store, SDN eNB encapsulates a data packet and sends it to UE.

Figure 8 shows the data delivery flow chart of content delivery operation at each network entity.

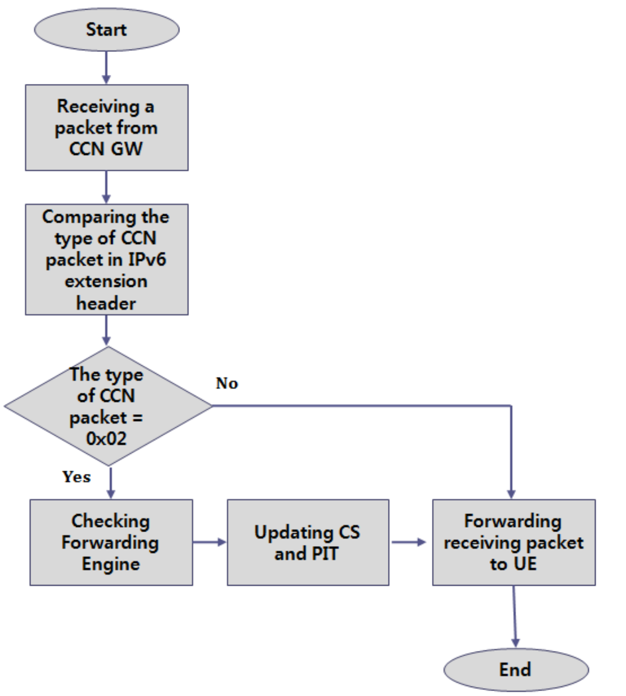

Figure 8. The Data Delivery Flow Chart of Content Delivery Operation at each Network Entity

When CCN GW receives data packet from outside CCN router, CCN GW encapsulates data packet into IPv6 packet, attaches CCN extension header and sets the type of CCN packet to 0x02. Every network entity checks the type of CCN packet. Then network entities decapsulates the received packet and updates its forwarding engine. They update their content stores and PIT. After updating forwarding engine, network entity sends the received packet to UE.

Using this scenario, after some time, if another UE request same content, the traffic does not reach to P-GW. When SDN eNB receive request from new UE, eNB's content store already contains a requested content. And this operation helps to reduce replica messages in the network and reduce total content delivery time.

3.5.2 The Operation of Node Mobility

In this paper, we proposed SDN based LTE framework. Via proposed framework, it is able to provide new mobility support in the LTE environment.

Figure 9 depicts the operation of supporting node mobility. In the current LTE, handover is determined from eNB. Each eNB measures RSSI from UE periodically. The current eNB compares RSSI value between current eNB and UE with other RSSI values between UE and other eNBs. If RSSI between UE and another eNB is larger than RSSI between UE and current eNB, it makes a decision to start handover. In our proposal, it is similar to current handover process in latest LTE. However, after sending handover preparing message, new eNB sends a packet-in-message to SDN controller in MME instead of sending various messages for x2 handover in current LTE [9].

MME which contains SDN controller receives a packet-in-message from new eNB. Then MME authenticates UE using Home Subscriber Server (HSS) [1]. After the authentication is finished, SDN controller checks the path to P-GW for the new eNB in the flow table. After finding a new path information or making a new path information, SDN controller sends a flow table update message to new eNB. Moreover, if intermediate switch is needed to update its flow table, SDN controller also sends update message to the intermediate switch.

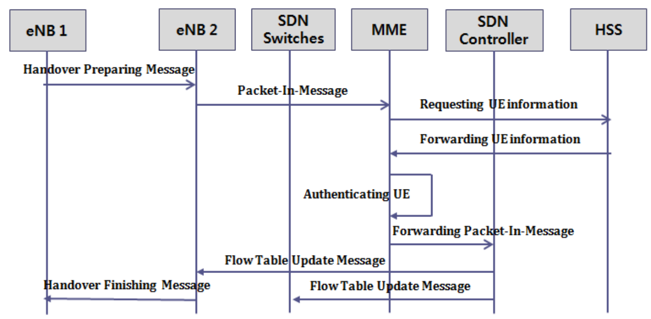

Figure 9. The Sequence Diagram of Node Mobility Operation

4. PERFORMANCE EVALUATION

To evaluate our proposed framework, we perform simulation using NS-3 [10, 11] and MININET [12] with fox controller [13]. For simulation, we set network environment as follows:

Table 3. Simulation Environment

Parameter	Explanation
The number of intermediate switches among network entity	10
The number of outside CCN routers	100
The number of outside nodes in Internet	100
The number of content sources in CCN network	Random
Link delay	10ms
The bandwidth between link	10Mbps
The size of content	200Mbyte
The size of chunk	1Mbyte

In figure 10, we can see that total content delivery time of proposed framework is similar to that of current LTE for the first content request. This is because at initial state, each network entity does not have a content in content store. However, for subsequent requests, proposed framework's total content delivery time is shown to less than current LTE starting from the second content request. From this evaluation result, If network entity has a content delivery function, it helps to reduce network overhead and total content delivery time.

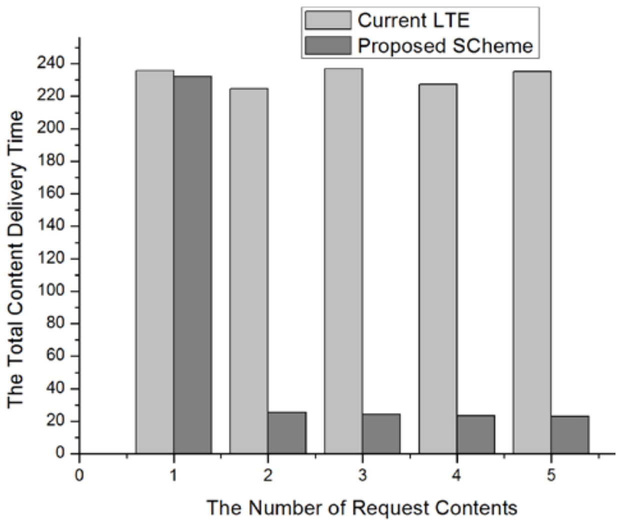

Figure 10. Comparison of Total Content Delivery Time between current LTE and Proposed Scheme

5. CONCULSION

In this paper we proposed a new SDN based LTE framework for supporting content delivery and for providing network management efficiently. Moreover, to distinguish normal packet and CCN packet, we proposed IPv6 extension header for CCN packets. Using proposed framework, we describe two scenarios which is providing content delivery and supporting node mobility. Via the simulation, we prove our proposed framework is better performance than current LTE environment in total content delivery time after finishing first content request.

For the future works, it is needed to consider an adaptation of SDN into CCN. Also it is necessary to adapt mathematical analysis for optimizing path selection.

6. ACKNOWLEDGMENTS

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