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Enhanced Multimedia Data Delivery based on Content-Centric Networking in Wireless Networks

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Abstract: There is a growing interest in content-centric networking which is a new networking paradigm where the content itself becomes the core of communications rather than the address or location. Content-centric networking is greatly useful to increase the content availability and the efficiency of content delivery. Currently, the content-centric networking architecture is at an early stage, and it is not clearly defined yet in the wireless environment. In this paper, we propose a possible architecture, necessary components, and related mechanisms for multimedia content delivery in the wireless network. The proposed architecture is based on content-centric networking. We also present various simulation results to show that the proposed architecture and associated mechanisms work well in the wireless network.

Keywords: multimedia, data delivery, content naming and routing

1 Introduction

The Internet has been greatly successful since its creation and has become a highway for globalization and an effective means for networking various devices and distributing information and services. Its size, complexity, and the role it plays in the modern world have far exceeded the initial expectations. It is now a complicated and constantly expanding architecture that has become an essential part of our lives, work, communications, and entertainment.

The high complexity and expansion of the architecture imply the increased exchange of contents, collaboration, and interactions. To meet the needs of various multimedia applications and services including voice/video over IP, crowdsourcing, social network services, and multimedia content sharing, researchers are trying to define a new Internet architecture which can support high availability, heterogeneity, mobility, security, and so on. Due to the rapid advancement of the Internet and wireless mobile technologies, mobile Internet users are able to access multimedia content and social information easily, and stay connected for various mobile applications and services.

Basically, there are two types of approaches to access multimedia content on the Internet. The first one is based on the improvement of the current host-based architecture: content delivery network (CDN) or peer-to-peer (P2P) network. The second one is based on the information-centric architecture: information-centric network (ICN) or content-centric network (CCN)

CDN is built on top of the IP-based host-to-host communication model where several dedicated servers store all the contents published. The content exists in multiple copies within strategically dispersed cache servers which are close to the user. Therefore, CDN can increase the hit ratio of the content and also minimize the service delay in delivering the requested content. However, CDN can be inefficient as it has the central authority to control content dissemination in the host-based communication model. On the other hand, P2P is a distributed network model in which each node (peer) acts as a client and also as a server. With the P2P model, services and contents are shared among the interconnected peers. P2P peers may contradict the traffic engineering policies of the underlying provider IP networks.

Typically, users are not much interested in the location itself from which the content is provided, but instead they

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are more interested in how soon they can access the desired content. To meet this objective and to overcome the challenges in the massive amount of content distribution, ICN/CCN has recently gained much interest.

Nowadays a large volume of multimedia contents are exchanged on the Internet and comprise about 60% of the total Internet traffic. Wireless networks are also becoming overloaded with multimedia contents due to the increasing number of mobile devices such as laptops, tablet PCs, and smart phones and are facing various communication challenges to provide efficient, reliable, infrastructure-independent, and scalable content delivery services. For efficient content delivery, it has been emphasized to focus on the content itself and decouple the content from the host in various research projects such as NDN, PERSUIT, DONA, and NetInf. However, the CCN architecture is not yet clearly defined in the wireless environment.

In this paper, we define a possible network architecture and necessary components for multimedia content delivery in the wireless environment. The proposed architecture is based on content-centric networking. We also propose a routing approach that constructs a route without the global network-wide information and a dependency on the central node and also drastically reduces the forwarding database information. In addition, we propose a smart handover approach to provide seamless continuity and reachability for the end user. The rest of the paper is organized as follows. Section 2 describes the recent work related to content-centric networking. Section 3 presents an architecture, necessary components, and related mechanisms for content delivery in the wireless network in detail. Section 4 presents our network model, and Section 5 discusses performance issues. Finally, Section 6 concludes the paper.

2 Related Work

DONA [1] introduces data-centric networking by replacing the concept of DNS in the traditional host-based Internet architecture. DONA proposes a flat, self-certifying name based approach. Each node is associated with a public-private key pair and its content is named using the form of node's public key: the node's signature of data. These names are application independent and unique, and ensure content integrity. DONA employs the Resolution Handler (RH) server to index the content provided by the content provider, and hosts are attached to a RH and make a query to the RH for requesting the content. Consequently, DONA reduces the applicability of name-based networking because it is actually location-based and always connected to a RH, and also for each connection it requires session re-establishment.

Network of Information (NetInf) [2,3] follows the similar naming approach as DONA and also relies on a name resolution service. The published content objects of the content provider use a self-certifying identifier to the locators for content discovery. NetInf uses Multilevel DHT (MDHT) [4] for name resolution and content lookup and also for global routing in the DHT area. However, NetInf reduces its scope by increasing its dependency on the name resolution system which is responsible for managing registration, updates, and accumulation of names. It requires a re-binding for the wireless environment similarly to DONA.

PERSUIT [5] proposes a publish/subscribe architecture that is comprised of three key components: Rendezvous, Topology and Routing. A Rendezvous Network (RN) is comprised of Rendezvous components which are interconnected by Rendezvous Identifier (RI) and Scope Identifier (SI) in a tree structure. The RN is responsible for publications and defines its scope based on the RI and SI. The RN makes a name resolution on a request for mapping an identifier to a published content. Then the Topology component constructs a path to the content source and the Routing component transfers the content using the source routing mechanism [6]. Similarly to NetInf, it also follows the name resolution based routing structure.

In [7,8,9,10], several routing policies and scalability issues regarding the content-centric approaches are described. These works rarely focus on how routing will be performed and how the forwarding information base (FIB) will be generated from a huge number of disseminated contents throughout the Internet and how the network architecture will be more responsive to the wireless mobile situation. In [11,12], a resource name based routing algorithm was introduced, which follows the present Internet architecture that limits the scope of the name-based routing. The content-centric networking architecture [7,13,14,15] decouples the content from the location and works like a virtual content distributor all over the network. It will increase the network overhead due to transmissions of the content request packet called Interest packet and transmissions of related routing packets for each content. Ant colony based routing [16,17,18] restricts the Interest packet dissemination and content distribution, but the overhead and the complexity of these algorithms are high due to the collection of global information.

CCN still has more issues to be resolved for practical applications, and user mobility is one of them. End user mobility architecture is not yet supported by the current CCN architecture. Several proxy-based approaches [19,20] were proposed to provide seamless connectivity towards the content when the end users are mobile and change its location eventually. But these approaches increase the complexity of handling mobility by increasing its dependency on a central administration or proxy server.

CCN [13] is based on the communication with the nearby locations where the content is available instead of the source-destination communication scenario.

Therefore, CCN can provide anytime, anywhere communication with respect to content access. In CCN, contents are accessed using the hierarchically arranged name components that are generated by the content providers. An Interest packet which includes the content name is broadcast towards all the available content providers' CCN nodes. Any node that has the original or a replicated copy of the requested content can respond to the request.

3 An Architecture for Enhanced Multimedia Content Delivery in the Wireless Environment

Although CCN is a promising architecture for efficient data delivery, it is still an evolving concept. In this section, we present a possible CCN-based architecture for multimedia content delivery in the wireless environment.

3.1 A Structure for Content Naming

The main principle of CCN is that a content is accessed using the content name rather than the host address, and thus content naming is a very important issue in CCN. With the exponential growth of multimedia contents on the Internet, it is difficult to find and organize relevant contents in an efficient way. Therefore, it is important to provide a well organized naming scheme that is flexible and provides a low delay in retrieving or identifying the content. Our proposed architecture follows a hierarchical structure for content naming, e.g., ’\hufs.ac.kr\videos\miss_imp.mpeg\V<1, 2> \S <1, 2>’. V and S represent version and segment, respectively, and the number of naming components is not limited. It is fully flexible for the content provider and takes the shape shown in Fig. 1. The CCN content names also implicitly contain the SHA-256 digest of the content to provide unique and data integrity.

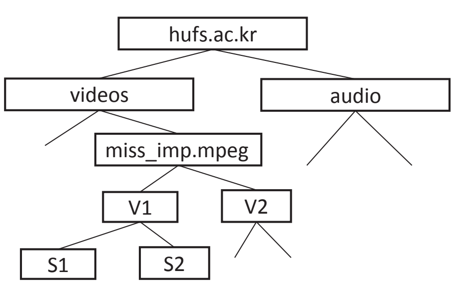

Fig. 1: A Naming Hierarchy

3.2 The Node Model

Each node in the network has three basic functional elements for content-centric communication: Content Store (CS), Forwarding Information Base (FIB), and Pending Interest Table (PIT) as in [13].

CS maintains the relation between the content name and stored content at the local cache of a CCN node. In our proposed architecture, we divide the CS into two elements: CS Index (CSI) and CS Repository (CSR). CSI holds the content name, Content Memory Pointer to the CSR, the Time-to-Live (LV), and the Number of Accessed Times (NAT). CSR holds the corresponding content only. We extend the traditional CS for increasing the flexibility of content management and content replacement. The basic structure of CS is shown in Fig. 2.

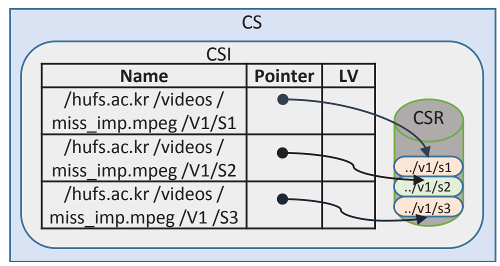

Fig. 2: Content Store (CS)

FIB contains the necessary information to forward an Interest packet to the appropriate next hop, which is similar to the routing table of the host-based network architecture. It contains all the next hop interface IDs for each reachable content. The basic structure of FIB is shown in Fig. 3.

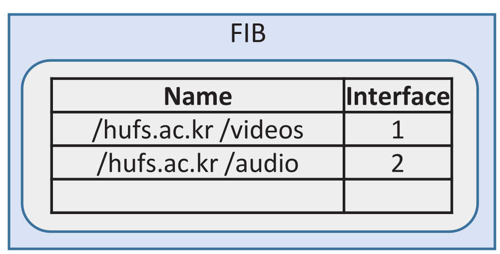

Fig. 3: Forwarding Information Base (FIB)

PIT is a fundamental structure to preserve the state of the received Interest packet. It records all incoming interface IDs for unsatisfied Interests so that it can satisfy the Interest later as soon as the content is available. Each PIT entry also holds the Time-to-Live (LV) to maintain its freshness. The basic structure of PIT is shown in Fig. 4.

PIT

Name	Interface	LV
/hufs.ac.kr /videos / miss_imp.mpeg /V1/S1	0	

Fig. 4: Pending Interest Table (PIT)

3.3 Components of the Proposed Architecture

The proposed CCN architecture is comprised of Smart Base Stations (SBS), Smart Routers (SR), Content Servers, and Mobile Devices as shown in Fig. 5. There are two types of SRs Proxy Routers and Autonomous System (AS) Routers. Several AS Routers form a group or a Content Autonomous System (CAS). CAS is connected to each other using the Proxy Routers. Network Engineers or ISPs have the complete flexibility to design the range of CAS. Content names are broadcast inside the CAS and aggregated content names are unicast among the different CASs using the Proxy Routers. There is no centralized intelligent controller, and the mobile devices are connected with SBSs using the X1 wireless interface. SBSs are connected to SRs using the X2 wired interface, and Content Servers are connected to the SRs using the X3 wired interface. SBSs are equipped with a mobility handler (e.g., MME in LTE) to deal with handovers of the mobile devices. The main reason for distributing the intelligence among the base stations in our proposed architecture is to reduce the response time for content delivery even during the handover. All the components in the figure follow the basic structure of the CCN node model.

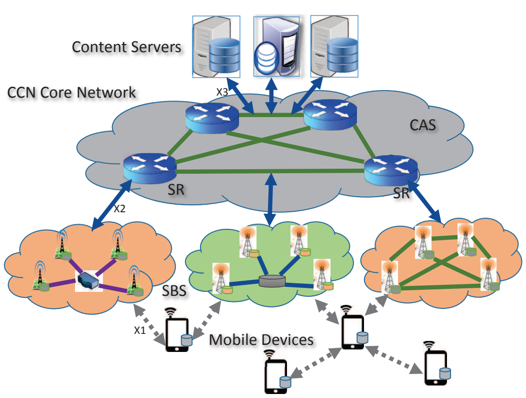

Fig. 5: The Proposed Architecture

3.4 Routing

CCN enables content name based routing without knowing the host address. This means that the contents are disseminated across the network; mobile devices retrieve the desired content by requesting with the appropriate content name; the content will be provided from the most appropriate content source.

CCN uses two types of messages for communication, namely, Interest packet and Data packet. The Interest packet is used to request for a particular content, and the content provider provides the requested content based on the content name. The Interest packet contains the content name and other identifiers, e.g., type, version, author, etc. Data packets are used to transmit the requested content to the requester as a response to the Interest packet. Data packets also contain the digitally signed information for protecting the content and respecting the content publisher. Interest packets may also contain a content name with a req flag, which implies the content provider needs to reply back with the exact content name, content meta-data (e.g., size, content provider, encoding scheme, etc.) and path attributes (e.g., bandwidth, hop count, etc.) using a Data packet that contains the content name with a special flag $dataReq$.

Content Providers may allow only valid requesters to access and store data by publishing the data items with a valid name. Each content is assigned a unique attribute according to the category of data items. A CCN node that intends to publish a content injects its name to its local CS and forwards the name into the network based on the scope.

The FIB prefix is learned in two ways. First, the content provider may broadcast, multicast, or unicast the content name or a prefix of a content name to the nearby neighbors. The prefix will eventually reach the core network routers. Second, each node may learn the FIB prefix by referring to the response of the pending Interest packet. Each router has a limited amount of storage capacity to handle FIB entries. In order to handle the scalability problem of FIB manipulation for a huge amount of real world contents, we set a storage threshold to 0.85. The storage threshold 0.85 means that a node can hold the 85% of its total storage for FIB manipulation. The remaining 15% are used for FIB updates. When a new FIB entry appears, the storage capacity of the node will be checked against the threshold, and if it is below the threshold, the entry is injected in the FIB, otherwise a FIB aggregation is performed, e.g., \hufs.ac.kr\videos and \hufs.ac.kr\audio to \hufs.ac.kr, the storage capacity will be checked again and the new FIB entry is inserted. Each Proxy Router in the core network has the ability to aggregate the FIB entries to its minimum level and to transfer towards the neighboring CAS. The network engineers or the ISPs should be aware of prefix aggregation to provide the faster, more efficient and scalable content access.

• A Simple Approach

Content Request: Content requesters broadcast an Interest packet to the nearby SBSs or SRs with the desired content name. An SBS or SR receives the Interest packet, looks up its CS for the requested content. If a matching content is found, then it will be sent out via the arrival interface as a response to the Interest packet. If the matching content is not found in the CS, a lookup is performed in the PIT. If there is an already existing PIT entry for the corresponding Interest packet for the same arrival interface, the Interest packet is discarded and the lifetime of the PIT entry is updated. If there is an already existing PIT entry for the corresponding Interest packet but the arrival interface is different, then a new PIT entry for the arrival interface is added to the PIT and the Interest packet is discarded. If there is no matching PIT entry, then a lookup is performed in the FIB. If there is a matching entry found in the FIB for the requested content, a new PIT entry is added to the PIT by assigning the lifetime that adjusts the time-to-live (LV) of the PIT entry, and the Interest packet is forwarded to the interfaces available in the FIB. An Interest packet is forwarded to a single interface according to the round-robin fashion or using the random probability to reduce the response time for the same content from different providers. It also makes faster retrieval of a large volume of multimedia contents by requesting small chunks of the contents from different content providers. If there is no match found in the FIB, the Interest packet is discarded, which means that there is no way to satisfy the content request. As shown in Fig. 6, Steps 1-5 and 9 are related to the content request. The pseudo code of this content request approach is presented in Algorithm 1.

Algorithm 1 : Content Request Algorithm at each node

INPUT: Interest(a request for content c from a content requester)

```
if c is not flagged with req then
    if c is in CS then
        Return c to the content requester
    else if c is in PIT then
        if the incoming interface is in PIT then
            Discard Interest
        else
            Update PIT by adding the interface
        end if
    else if c is in FIB then
        Forward Interest to the next neighbor
        Add c to PIT
    else
        Discard Interest
    end if
else if c is flagged with req then
    exit and Go to Algorithm 3
end if
```

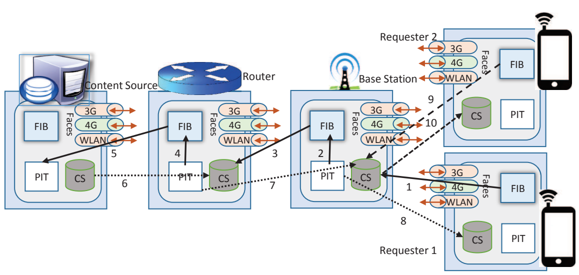

Fig. 6: Routing in the Proposed Architecture

Content Retrieval: Contents are delivered back to the content requester using the forwarding route of the Interest packet to the content source. When a Data packet is received by the base station or router, it looks up its CS. If a matching entry for the received content is found on its CS then it discards the content because the content is duplicated and received previously. If there is no corresponding matching entry in the CS, it looks up its PIT to find any Interest unsatisfied for the corresponding content. If there is a match in the PIT, the content is stored in the CS and forwarded to the interfaces in the PIT. After successful forwarding, the PIT entry is removed. If there is no match found in the PIT, the content is discarded and not processed further. As shown in Fig. 6, Steps 6-8 and 10 are related to the content retrieval. Pseudo code of this content request approach is presented in Algorithm 2.

Algorithm 2 : Content Retrieval Algorithm at each node

INPUT: Data(content c from a content provider)

```
if c is not flagged with reqData then
    if c is in CS then then
        discard c
    else
        if c is in PIT then
            forward c to the interface
            and remove c from PIT
        else
            discard c
        end if
    end if
else if c is flagged with reqData then
    exit and go to Algorithm 4
else
    discard c
end if
```

• A Reliable Approach

In the simple approach, the Interest packet may be disseminated to the different content providers, and the same content may be replied back to the content requester using multiple different routes. This will misuse the network resources and badly increase the network overhead due to the unnecessary content transfer using different routes. To reduce the network overhead and to increase the bandwidth efficiency, we introduce the following reliable approach for the proper route selection.

A Route for Content Request: Content requesters unicast an Interest packet to the nearby SBSs or SRs with the desired content name by adding an additional flag (req) inside the content name. An SBS or SR receives the Interest packet, looks up its CS for the requested content. If an exactly matched or a larger prefix matched content is found, then it will be sent out in a data packet that contains the exact content name with an additional flag dataReq, other attributes (e.g., size, encoding types, etc.) and the path related information (e.g., bandwidth, current load, etc.) via the arrival interface as a response to the Interest packet. If the matching content is not found in the CS, a lookup is performed in the PIT. The other operation is similar to the content request functions described in the simple approach. The algorithmic presentation of this part is shown in Algorithm 3. When the core routers receive the data packet $dataReq$, it looks up its FIB. If an exactly matching entry for the named content is found in its FIB then it calculates its current weight value using Eqn. 1. If the weight value is greater than the previous weight value, then the FIB interface is updated, otherwise the data packet dataReq is discarded. If there is no corresponding matching entry in the FIB, the incoming interface is stored in the FIB with a LV value equal to the half of the normal LV value and weight value equal to the calculated value using the Eqn. 4 and forwarded to the interfaces in the PIT. After successful forwarding, the PIT entry is removed. The algorithmic approach for receiving dataReq is illustrated in Algorithm 3.

Algorithm 3 : Route for Content Request, at each node

INPUT: Interest(a request for content c from the content requester)

```
if c is flagged with req then
    if c is in CS then
        return dataReq to the content requester
    else if c is in PIT then
        if incoming interface is in PIT then
            Discard Interest
        else
            update PIT add interface with req flag
        end if
    else if c is in FIB then
        forward interest to the next neighbor
        add c to PIT with req flag
    else
        discard Interest
    end if
else if c is not flagged with req then
    exit and go to Algorithm 1
end if
```

Contents Retrieval: Data packets with the meta-data of the contents are delivered back to the content requester using the forwarding route of the Interest packet to the content source. When a Data packet dataReq is received by the content requester it unicasts an Interest packet using the previously found forwarding route using the section Route for Content Request. The other operations are the same as the content request functions described in the simple approach and illustrated in Algorithm 1, and content retrieval functions described in the simple approach and illustrated in Algorithm 4.

Algorithm 4 : Route for Content Request, at each node

INPUT: INPUT: Data(content c from a content provider)

```
if c is flagged with reqData then
    if c is in CS then
        discard c
    else
        if c is in PIT with req flag then
            forward c to the PIT interface
            remove c from PIT
            measure the route weight using Eqn. 4
            if c is in FIB then
                if current weight ¿ existing weight of FIB then
                    update FIB with the current interface
                    delete the old one
                else
                    discard c
                end if
            else
                add c to FIB
            end if
        end if
    end if
else if c is flagged with reqData then
    exit and go to Algorithm 2
else
    discard c
end if
```

3.5 End User Mobility

It has been shown that CCN works in a network with mobile nodes, but several problems arise with real-time applications when nodes become mobile and the content size becomes larger. The current CCN architecture is not mature enough to support mobility for real-time multimedia communication as it cannot guarantee session continuity and reachability is not given for the tolerant time period. Fig. 7 illustrates User Equipment 1 (UE1) currently receiving a content via Access Network A moves towards Access Network B. If Access Network B does not have the routing information regarding the content, the session continuity cannot be maintained until the FIB entry of the content is updated. This paper proposes a soft-handover approach where the routing information on the new access network is updated before

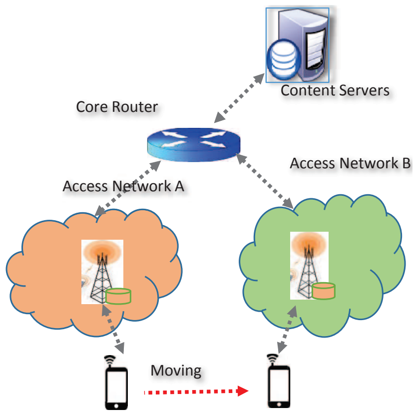

Fig. 7: A Mobility Scenario

the original handover occurs. This is almost similar to the follow-me service that is the modern trend of mobile communications. In our approach, the SBS has the capability that measures the traffic rate and the signal strength. the SBS can also apply the utility functions shown in Eqn. 4 to measure the overall weight with respect to the UE in order to decide whether the UE will move to a new SBS access network or not. If the old SBS detects a possible handover of the UE, it forwards the content name and the related information to the new SBS, and the new SBS forwards the Interest to the core network to retrieve the content. If successful, the UE terminates the connection to the old SBS and attaches to the new SBS and continues to receive the content seamlessly using the new SBS. The handover procedure is illustrated in Fig. 8.

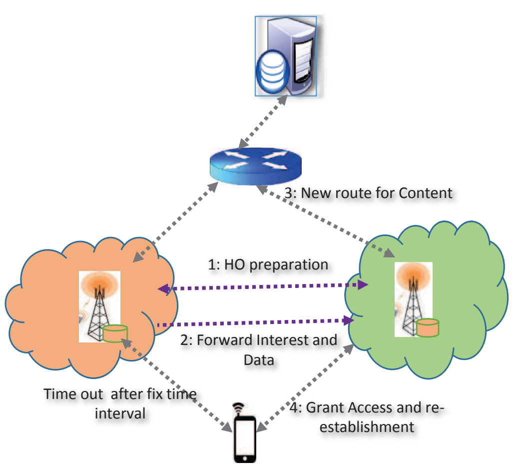

Fig. 8: Handover Procedure

4 The Network Model

In our network model, we consider a number of Smart Routers, Proxy Routers, Smart Base Stations, Mobile devices and Content Servers that are presented into a weighted graph $G(V, E)$. The V is the number of CCN-enabled nodes, and E is a set of connected interfaces among them. Each node in the network model follows the decision problem of computation theory where yes or no is converted to $'found'$ or $'notfound'$. Content retrieval is an NP-hard problem where the more the content information will be learned by the network, the faster the content will be retrieved. We assume that n different nodes are uniformly distributed in a square area. We assume that at least one of the routing messages corresponding to FIB generation is eventually delivered to all nodes. Under this assumption, the number of routing messages due to flooding is $O(n)$ and the number of routing messages at each node is $\log_b x$ where b is the depth level of the content name aggregation and x is the total number of content entries that are in the FIB. Let p denote the probability of the forwarding inefficiency of a node. Then the probability of an Interest message sent over h hops can be expressed as:

$$P(h) = 1 - (1-p)h \tag{1}$$

and the expected number of hops that the Interest message traverses is as follows:

$$H(h) = \sum_{i=1}^{n} \frac{(1-p)^{i-1}p}{P(h)}.i \tag{2}$$

• Utility Function: We define a mathematical function capable of taking into account receiver's preference in terms of criteria while selecting a route for content transfer. Let x be the different value for a single criteria within the varied range $x_{min} \leq x_m \leq x_{max}$, α be the steepness and x_m the midpoint of the variation range. These variations can be defined as a single criteria utility function as follows:

$$u(x) = \begin{cases} 0 \; if \; x \leq x_{min} \\ \frac{1}{1+e^{\frac{\alpha(x_m - x)}{x - x_{min}}}} \; if \; x_{min} < x \leq x_m \\ 1 - \frac{1}{1+e^{\frac{\beta(x-x_m)}{x_{max}-x}}} \; if x_m < x \leq x_{max} \\ 1 \; if \; x \geq x_{max} \end{cases} \tag{3}$$

where $\beta = \frac{\alpha(x_{max}-x_m)}{x_m - x_{min}}$ and $\alpha > 0$ are the tuned steepness parameters. The proposed utility function satisfies the following properties: $u(x) = 0 \; \forall \; x \leq x_{min}$, $u(x) = 1 \; \forall \; x \geq x_{max}$ and $u(xm) = 0.5$. Route selection in the networking environment is based on an aggregation of different utility functions for decision processes. Hence, we define here a multi-criteria utility function that is able to integrate the receiver's different choice metrics to select a better route. Let's assume that R is a route on which $dataReq$ message is traversed, which can be described as a one different descriptor or multiple attributes (e.g., bandwidth, delay, and cost in terms of hop count), i.e., $x = x_1 * ... * x_n$. Each alternative attribute can be described as a utility function $u(x_i)$, and the simple weighted average of a route A_R is used to maximize the probability of selecting the best route as follows:

$$A_R = \sum_{i=1}^{n} w_i u(x_i) \quad (4)$$

where w_i is a weight that reflects the content receiver's preference. Weights are assigned depending on the receiver's expected criteria, and thus the expected criteria have a higher weight.

5 Simulation Results

We implemented the proposed CCN architecture and the routing mechanisms using NS-3 and CCNx [13] on a Linux Ubuntu environment. The primary goals of our implementation were to show the performance characteristics of the proposed architecture with respect to CCN functionalities in the wireless environment and to ensure that the proposed architecture and the routing mechanism work well with the CCN functionalities in the various wireless networks, e.g., Wi-Fi, LTE, and CSMA/CD-based networks. The proposed architecture delivers the content to the requesters that are interested in the particular content in a fast manner. We also performed simulations to show the effectiveness and responsiveness of our proposed work towards mobility for real-time multimedia communications. We used Content Transfer Time as a key performance indicator, and it is normally measured from the time at which a user requests for a certain content to the time at which the content is provided. Note that the network capacity and types of traffic flows may affect the content transfer time. Assigning weights for the utility function of Eqn. 1 depends on the receiver's preference. In this paper, we did not consider the assignment of each weight for optimizing the performance. For our simulation purposes, we used three routing attributes, e.i., hop count, bandwidth, and the number of active connections, and their weight values are 0.6, 0.25 and 0.15, respectively to define the utility function. The required parameters related to the simulation are specified in Table 1.

Table 1: Simulation parameters

Parameter	Value
Network Type	LTE, Wi-Fi, CSMA/CD LAN
Simulation Time	400 Sec
No of Content Server	1
Size of the Content	10
Transport Layer	UDP
Bandwidth	8Mbps, 10 Mbps, 1 Gbps
Delay	2 ms
Content Packet Size	1024 Bytes

5.1 Scenario 1

Fig. 9 shows a simulation topology with heterogeneous access networks where the content server has a 10MB file, and remote user devices want to download the file. The performance of our proposed architecture has been evaluated and compared with the current Internet architecture and the conventional CCN architecture. We

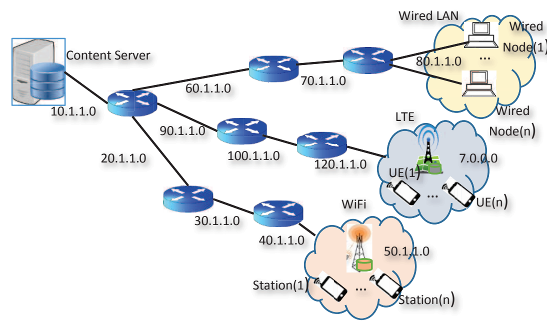

Fig. 9: A Simulation Topology with Heterogeneous Access Networks

assigned three different routes for each access network to the content server. There are 10 different end user nodes at each access network, and they request for the same content from the content server in a random interval, which means some end user devices start to download the file at 10 sec, and some user devices to start to get the file at 13 sec. Scenario 1 is to show how well the proposed architecture works with the smart base stations when the mobile clients download the file. Fig. 10 shows the average result of simulation for each node resides at the different access network based on Scenario 1. It took

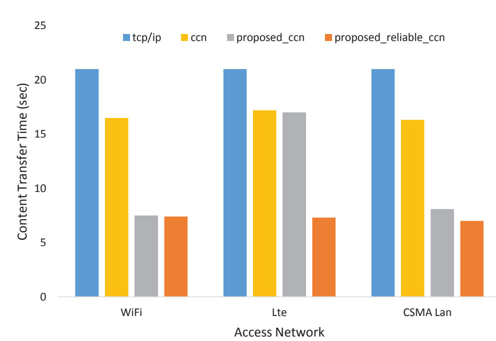

Fig. 10: Content Transfer Time in Different Access Networks

about 21 seconds for the user devices to download the file using pure TCP/IP and took about 7.5 seconds when our proposed architecture is used. However, the content transfer time, i.e., response time, is much shorter than the download time after the first retrieval because of caching at smart base stations which follow the CCN approach. When the file downloads happen simultaneously at the first request, the channel which connects the content server and the router suffers from traffic congestion, so the large download time is required when simulation is performed on the conventional CCN. However, with our proposed architecture, less download time is needed because of a better route for content transfer. The simple approach forwards the Interest randomly, and therefore sometimes it selects a congested route so it requires some more time to retrieve the content than the reliable approach. The proposed reliable approach needs less time because of its judicious choice of the route before the actual content transfer begins.

5.2 Scenario 2

Fig. 11 shows the second simulation topology with the LTE access network where a 10 MB file is contained in the content server and UEs download the file simultaneously from the content server. While increasing the number of UEs, we measured the average download time for the content. Fig. 12 shows the simulation result

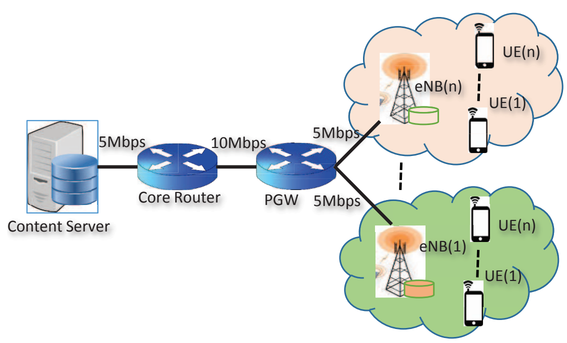

Fig. 11: A Simulation Topology with the LTE Access Network

where we present the performance of the conventional CCN-based architecture and the proposed CCN architecture. In this simulation, we tried to figure out the scalability performance of our proposed architecture when the number of end users for the same content is increased. As shown in the figure, as the number of UEs is increased, the performance of our proposed architecture is better than the conventional CCN architecture in terms of average download time because of its network-wide balanced route construction and also the exchange of limited number of routing information. We have also

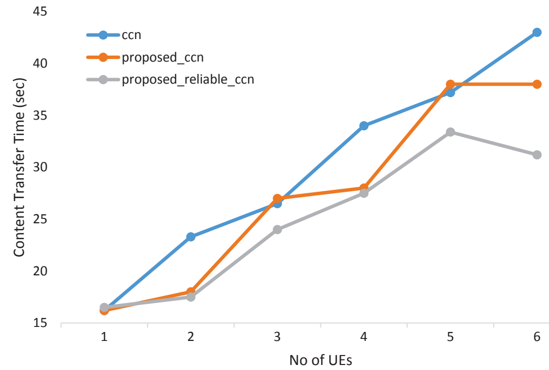

Fig. 12: Content Transfer Time for Different Number of UEs

measured the performance of reachability and continuity of our proposed architecture in terms of content transfer time, which implies that how fast UEs can retrieve the content in a mobile environment where the UE moves at a speed of 20 m/s from one SBS to another SBS. A single UE was moved up to 5 SBS during the time of 10MB content transfer. Fig. 13 shows that our proposed architecture is much more responsive than the conventional CCN approach because it retrieves the content at the new SBS before the original handover to the new SBS occurred.

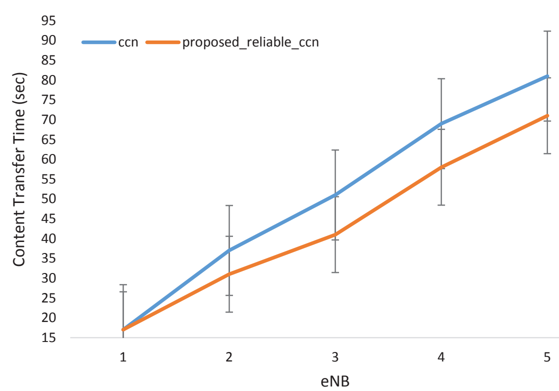

Fig. 13: Content Transfer Time for Different Number of eNBs

6 Concluding Remarks

In this paper, we proposed a possible architecture, necessary components, and related mechanisms for multimedia content delivery in the wireless environment, which is based on content-centric networking. The key components of the architecture include smart base stations, smart routers, and content access mechanisms. The proposed architecture can provide multimedia data delivery efficiently and therefore reduce the response time significantly. We also proposed a routing approach that constructs a route without the global network-wide information and a dependency on the central node and also drastically reduces the forwarding database information. In addition, we proposed a smart handover approach to provide seamless session continuity and reachability for the end user. We presented various simulation results to show that the proposed architecture and mechanisms work well in the wireless network.

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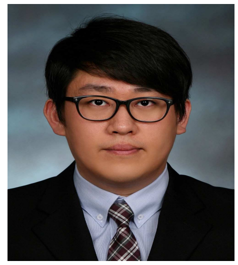

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