A Comparative Study on Mobile Content Delivery Networks

Mohammad H. Al Shayeji, Sa'ed Abed, Aisha E. Bourahma, M.D. Samrajesh

Computer Engineering Department, College of Computing Sciences and Engineering,
Kuwait University, Kuwait
e-mail: m.alshayeji@ku.edu.kw, s.abed@ku.edu.kw , eng.aisha.e@gmail.com,
sam@differentmedia-kw.com

***Abstract*— The exponential growth of mobile devices has a significant role in the generation and sharing of digital content. A Content Delivery Network (CDN) is a collection of servers and networking components used for effective delivery of content to end-users. As access to mobile-based applications tend to grow, Mobile Content Delivery Networks (MCDNs) play a crucial role in distributing digital content to mobile end users. MCDNs improve the delivery of content by providing the user requested data from closer location there by decreasing the network traffic and latency. However, there is a lack of study on the various mobile content delivery models available. In this paper, we classify the different approaches of MCDN based on caching and replication, and study their features, and their functionalities. Moreover, we describe the various merits and demerits of each mobile content delivery method.**

Keywords- Caching; Media Streaming; Mobile Content Delivery Networks; Replication; Wireless Network.

I. INTRODUCTION

Today, mobile devices are very popular and they produce and consume significant amount of digital data. Together with data produced from fixed devices, digital content grow exponentially due to popular applications such as mobile television, mobile Video on Demand (VoD), social media, live traffic information, location based services and much more [9]. There is a need for efficient delivery of digital content to the end users [15]. Delivery of content to mobile devices is much more challenging than fixed devices as the bandwidth, signal strength, energy etc. of the devices play a crucial role in the delivery and transfer of the content.

Customary fixed Content Delivery Networks (CDNs) provide a scalable and cost-effective way of content delivery. However, the design of existing CDNs is inadequate for wireless devices where the end users mobility is high. Mobile Content Delivery Network (MCDN) improves the delivery of content by providing the user requested data from a closer location. Mobile network operators can achieve up to 30% faster mobile content delivery as well as up to 20% reduction in mobile data traffic using MCDN [8].

A classification and survey of CDNs is presented in [16]. It described a regular CDN's organizational structure, content distribution mechanisms, and user request redirection techniques. The paper mapped the classification to existing CDNs to demonstrate its applicability and analyze CDNs. Moreover, it identified the strength and weaknesses. However, it does not consider mobile CDN implementations.

A survey on content delivery acceleration in mobile networks is presented in [5]. The paper classified the acceleration solutions in mobile networks into 3 main sections: first the mobile system evolution, second the content and network optimization, and finally the mobile data offloading. However, it only considered mobile CDN in the mobile system evolution.

Streaming media content for mobile CDN is presented in [22]. This approach streams content for large-scale mobile media delivery services. The MSM-CDN is a virtual overlay network placed on top of Internet Protocol (IP) networks; it is a set of managed or self-managed overlay nodes that work together to deliver media streams to mobile users. However, an implementation of the proposed method is not performed and evaluated.

The challenges of video distribution and mobility management, with respect to Quality of Service (QoS) and Quality of Experience (QoE) is presented in [18]. The paper concluded that MCDN enhances video transport using caching strategies. Moreover, the paper proposed a complete MCDN framework based on popularity based approach. The paper did not consider other performance aspects of MCDN apart from the popularity of content.

In this paper, we present a comparative study of different MCDNs implementations and their features. Moreover, we analyze the various advantages and disadvantages for each method and contrast between them. We focus on content availability and content retrieval mechanism using caching and replication. The paper is organized as follows. The related works on CDN and MCDN is presented in Section II. The study and comparative analysis of various MCDN is presented in Section III. Section IV concludes the paper and presents the future directions.

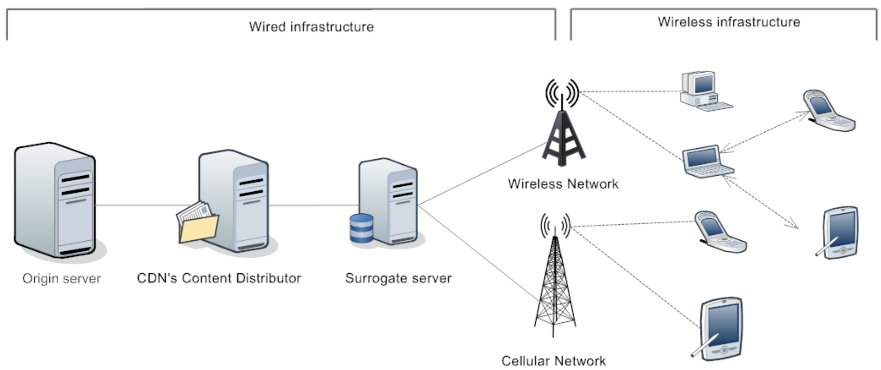

Figure 1. Typical CDN infrastructure

II. RELATED WORKS

A Content Delivery Network (CDN) is collection of interconnected servers used for effective delivery of content to end-users [6]-[7][16]. CDN's infrastructures can be centralized, decentralized or hierarchical. The delivery of content is done using content replication. The best replication strategy makes effective content delivery and overcomes traffic congestion. CDN based replication or caching strategy is done by placing different edge servers (i.e. surrogate server) near the users to act as a mirror to the original content server [1][18]. The content can be either static or dynamic, audio or video, text or image or a full web page. Content is placed in at least one server in the network. The original content server is generally termed as source server.

All CDNs have the following connections: the first is between the original content provider and the CDN providers; the second is from CDNs provider to the Internet service provider. Even though CDNs have improved the delivery of services to the user, it is not efficient for mobile users, as the mobility of users impacts the performance, and mostly the user demand in this situation is dynamically varying. Moreover, there are lots of other constraints that mobility imposes on the system such as signal strength, energy etc. Hence, mobile CDNs play an important role in delivering content to mobile end users [14].

A Mobile CDN is a network of servers, systems and mobile devices that cooperate and work together for an effective delivery of content to end users using a wireless network [12]. The goal of a mobile CDN is similar to that of typical CDNs, that is, to serve content to end users with low latency and high performance. In addition, Mobile CDN optimizes content delivery to end user regardless of various constrains in the mobile networks [8].

A typical infrastructure of mobile CDNs is shown in Figure 1. The figure comprises of the following parts: (a) Wired CDN infrastructure and (b) Wireless CDN infrastructure [15]. The wired part has the elements of the typical CDN but with different management algorithms (i.e., links between origin servers and surrogate servers, surrogate servers with network elements such as routers, switches 3G/GSM enabled base station and Wi-Fi enabled access point). The wireless infrastructure part contains the links between static and mobile devices. The basic communication here is (a) between the client and the edge of the wireless network (i.e., Wi-Fi or cellular), (b) between the edge of the wireless network and the surrogate server, (c) between the surrogate server and the origin server.

Information dissemination based mobile CDN(s) is presented in [15]. The recent advancements in wireless networking infrastructure and the challenges in mobile CDNs are discussed. Moreover, the paper investigated the network infrastructures of mobile CDNs, and explored on how information dissemination can be improved using MCDN.

MCDN works in ad-hoc networks such as MANET (Mobile Ad hoc NETwork) or VANET (Vehicular Ad hoc NETwork). MANET is a self-configuring infrastructure less network of mobile devices connected wirelessly [3][19][23], and VANET uses vehicles as mobile nodes to create a mobile network. Our paper focuses on the mobile content delivery in network that could either be one with a centralized infrastructure or an ad-hoc network. The communication in the centralized infrastructure is between the end users and the wireless access point or base station of the cellular network. In case of an ad-hoc network, the communication is between the end user and the wireless content provider.

III. COMPARATIVE STUDY OF MCDN

We study six MCDN approaches. 1) Mobile Dynamic Content Distribution Network (MDCDN) [1]. 2) Mobile Streaming Media Content Delivery Network (MSM-CDN) [22]. 3) A popularity based approach for the design of mobile content delivery networks [18]. 4) SCALAR: Scalable data lookup and replication protocol for mobile ad hoc networks [2]. 5) Novel architecture for a mobile content delivery network [21]. 6) Mobile caching policies for Device-to-Device (D2D) content delivery networking [11]. Figure 2 shows the classification of MCDN based on caching and replication.

Table 1 presents a comparison of different approaches in MCDN. The approaches are of type either content replication or caching or mixed type. The design in [18] uses the most accurate and effective calculation of popularity; however, the

TABLE 1. COMPARISON OF MOBILE CONTENT DELIVERY NETWORKS (MCDN)

S#	Approach	Type	Description
1	MDCDN : Mobile Dynamic Content Distribution Network [1]	Replication	• Content replication or removals of previously created replicas in the servers are done based on spatial distribution of client demand for that object. • A predictable demand online heuristic algorithm is used to reach the exact replication in each node with the lowest redundancy between nodes. • Content replication is either total content or partial content
2	MSM-CDN : Mobile Streaming Media Content Delivery Network [22]	Mixed - Replication and Caching	• A customizable media management system that can be either centralized or distributed or hierarchical is used • Both push and pull data strategies are applied. • Replicating data depends on 3 factors 1) popularity, 2) size of the segment and 3) cacheability.
3	A popularity based approach for the design of Mobile Content Delivery Network [18]	Caching	• A centralized system management for video distribution. • Two levels of popularity are used 1) global and 2) regional. • The system is integrated with dynamic adaptive streaming over Internet and the videos are partitioned into several segments.
4	SCALAR: Scalable data lookup and replication protocol for mobile ad hoc networks [2]	Replication	• Works based on virtual backbone construction algorithm. • Reactive Replication (RR) mechanism is used for replication. • The replication decision depends on the cost and the location of the request.
5	Novel Architecture for a Mobile Content Delivery Network [21]	Caching	• Proxy Mobile Internet Protocol version 6 (PMIPv6) based mobile CDN aims to reduce the link stress and hop count. • Cache servers are placed with the Local Mobility Anchor (LMA) and Mobile Access Gateway (MAG). • Proxy mobile IPv6 provides session continuity when roaming.
6	Mobile caching policies for Device-to-Device (D2D) content delivery networking [11]	Caching	• Designates mobile devices as caching servers, which provides near-by devices popular contents on demand. • Content is stored such as to minimize the average caching failure rate. • Presents a low-complexity search algorithm, which offers dual searching algorithm.

traffic between the nodes and the core router is high. MDCDN uses a predictable heuristic algorithm to determine the exact replication in each node. The temporal and spatial client demand are considered, it reconfigures the system, such as to minimize network traffic. MSM-CDN replicates data based on 3 factors 1) popularity, 2) size of the segment, and 3) cacheability. The popularity-based approach for the design of mobile content delivery networks [18] uses two levels of popularity, global and regional, to determine the content to replicate. Scalar uses Reactive Replication (RR) mechanism for replication. Moreover, the replication decision depends on the cost and the location of the request. Scalar is suitable for any kind of data either static, or dynamic including video streaming. The Novel Architecture uses Proxy Mobile Internet Protocol (PMIP) [21]. Mobile caching for Device-to-Device (D2D) [11] is more reliable as content is stored in devices such that it minimizes the average caching failure rate.

Table 2 lists the merits of the different MCDNs. The ability of uploading content by the end user using mobile

TABLE 2. MERITS OF THE DIFFERENT MOBILE CONTENT DELIVERY NETWORKS (MCDN)

S#	Approach	Merits
1	MDCDN : Mobile Dynamic Content Distribution Network [1]	• The replication mechanism is simple. • The decision of replica location depends on the geographical demands such as to reduce the total network traffic [26]. • The management of the system is distributed and executed by each node independently [24].
2	MSM-CDN : Mobile Streaming Media Content Delivery Network [22]	• Its flexibility and modularity allows it to be scalable. • Video uploading from mobile user to the infrastructure is supported [15]. • Supports stream scheduling. • The system can deliver a full video or a segment of the video.
3	A popularity based approach for the design of Mobile Content Delivery Network [18]	• Efficient popularity calculations for small number of regions. • Takes advantage of the correlation between two adjacent nodes eases the problem of request routing. • Supports different sizes of nodes caches depending on regional requests [22].
4	SCALAR: Scalable data lookup and replication protocol for mobile ad hoc networks [2]	• Due to its virtualized backbone structure, its ability to be scaled up is high. • Effective for MANET implementation. • Suitable for any kind of data either static or dynamic including video streaming.
5	Novel Architecture for a Mobile Content Delivery Network [21]	• Do not require any supplementary space as the cache servers are placed with the LMA and MAG. • Offers session continuity for highly mobile end users. • The overall network traffic is reduced by minimizing link stress.
6	Mobile caching policies for Device-to-Device (D2D) content delivery networking [11]	• The performance of optimal caching probability is compared Equal caching Probability (EP) and High-Priority-First selection (HPF). • The search algorithm has low complexity hence offers better search performance.

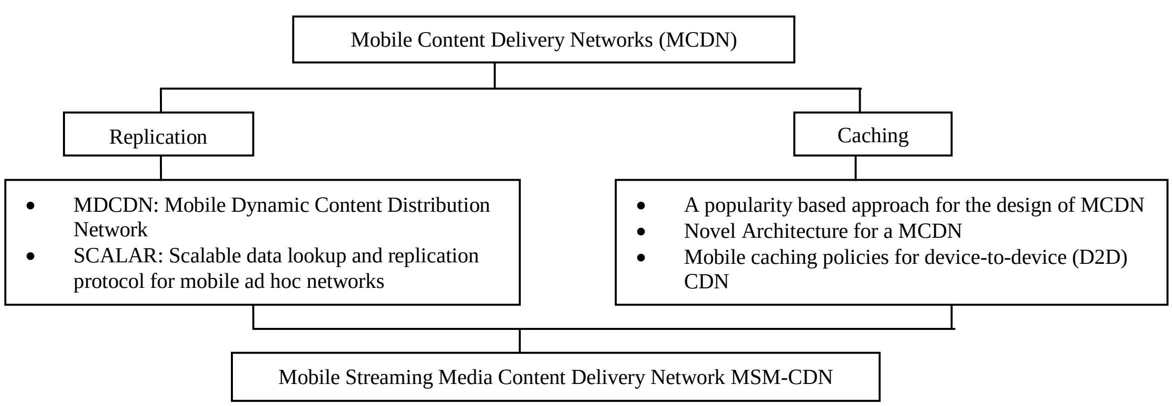

Figure 2. Classification of Mobile Content Delivery Networks (MCDN)

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TABLE 3. DE-MERITS OF THE DIFFERENT MOBILE CONTENT DELIVERY NETWORKS (MCDN)

S#	Approach	De-merits
1	MDCDN : Mobile Dynamic Content Distribution Network [1]	• The probability of content misses in the nearest node to the user is higher [11]. • The data is available in the closest server (to the client) only after the other client requested it, not before the request [5]. Hence, the first user will have delay. • Extensive content replacement is done since it depends on user requests [25][20]. • User can only download data; user upload is not possible [15].
2	MSM-CDN : Mobile Streaming Media Content Delivery Network [22]	• Too many customizations make the system sensitive to errors and failures. • The ability of delivering a full video is applicable for small networks, but for larger networks, network data congestion may occur.
3	A popularity based approach for the design of Mobile Content Delivery Network [18]	• All popularity database recorded should be send to a core router in ΔT, which increases the network traffic. • Complex and not realistic to be implemented for large number of regions. • Applicable for centralized Mobile CDN only [15]. • A user cannot upload data, only downloading is allowed.
4	SCALAR: Scalable data lookup and replication protocol for mobile ad hoc networks [2]	• Not recommended for centralized network. • Has computation overhead since it has extensive computations and complex replication mechanisms.
5	Novel Architecture for a Mobile Content Delivery Network [21]	• Ideal for multimedia content not suitable for other applications • As multiple Local mobility anchors (LMA) are configured, LMA selection becomes an issue [10].
6	Mobile caching policies for Device-to-Device (D2D) content delivery networking [11]	• The regularity conditions for Karush-Kuhn-Tucker (KKT) conditions are not mentioned in the paper [13]. • Energy of the mobile device is not considered while considering the device for caching [11].

device to the MCDN server is missing in most approaches. SCALAR is effective for mobile ad-hoc network implementations. Caching in [21] uses PMIP and the cache servers are placed with the LMA and MAG therefore it does not require additional space. Highly mobile end users may move from one location to another hence session continuity is essential. The network traffic is reduced by minimizing the link stress, i.e., the total traffic. Mobile caching policies when compared, D2D [11] outperforms Equal caching Probability (EP) and High-Priority-First selection (HPF). Moreover, the search algorithm has low complexity, hence offers faster searches.

The demerits of the approaches are given in Table 3. In MDCDN [1], the probability of content misses in the closest node to the user is high since the replication in each node has sharp boundaries [11]. It supports only download data. Moreover, if user requests different content extensive content replacement is done [25]. In Mobile Streaming Media Content Delivery Network MSM-CDN [22], network congestion may occur when entire videos are replicated. The popularity based [18] has an extra overhead in sending data to core routers. Moreover, it is designed for centralized CDN. User uploads are not allowed. Scalar [2] uses complex replication mechanism and is ideal for distributed MCDN. Novel architecture [21] is ideal for multimedia content and not suitable for other applications as the MCDN is based on media caching. However, when multiple Local Mobility Anchor (LMA) is configured, LMA selection becomes an issue [10]. Mobile caching policies for D2D [11] is based on Karush-Kuhn-Tucker (KKT) However, the regularity conditions for KKT conditions are not specified. Moreover, while selecting candidates for caching, the mobile device's energy is not considered [11]. Peer-to-peer file sharing applications using CDN is growing in popularity nowadays [26]. However, most existing CDNs have not capitalized it.

IV. Conclusion and Future Work

We presented a study of six different implementations of Mobile Content Delivery Network (MCDN). The comparison study examines the strategy used for content delivery i.e., replication, caching or mixed type (replication and caching). A description of each approach is presented. Moreover, the advantages and disadvantages of each approach are detailed. For a commercial CDN provider, adapting the MSM-CDN approach is most suitable. As the usage of social media is growing, a framework that depends on dissemination of data based on users access pattern and profile is more effective. Additionally, the study finds that in most MCDN implementations, the ability of uploading content by end user using mobile devices to the MCDN servers was missing. As a part of future work, we plan to design and develop a new algorithm for effective content uploads in MCDN using P2P approach.

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