2013 INTERNATIONAL CONFERENCE ON COMPUTING, ELECTRICAL AND ELECTRONIC ENGINEERING (ICCEEE)

On the Cache Performance of the Information Centric Network

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***Abstract*—The current Internet model has proved more sustainable then the provisioned capacity at the time when the architecture was designed. The voluminous growth of traffic over the Internet has brought challenges for the exiting networking architecture. The information centric paradigm appears to offer efficient solution towards content dissemination model. It is a content-focused networking paradigm rather than host-to-host communication. Caching is one of the major components of information centric networks. This paper is intended to explore the impact of cache on critical attributes of networks. We have made a comparative analysis of in-network and edge network caching mechanism using network simulation. The results proved that in-network caching mechanism is far better than network edge caching with improved throughout, increase link capacity to avoid congestion.**

Index Terms— Information Centric Networking, Named Data Networking, Cache Performance.

I. INTRODUCTION

The proliferation of contents over the Internet was observed massively in the last decade. The design of current networking architecture was based on host-to-host communication. The basic exchange of contents in the network was considered while designing the Internet. Gradually the use of Internet augmented with the huge exchange of data. Multimedia traffic such as voice and video streaming are being accessed from users. Social networking increased the pictures and video sharing massively. Contents are expected to occupy much higher volume than the current growth [1]. According to [2], the major part of 96% of Internet traffic based on user generated contents. Research industry made efforts to find out the solution to cope with the voluminous growth of data over the Internet. Information Centric Network (ICN) [3] paradigm appeared as result of researchers' contributions for efficient content distribution. The ICN is a named-based networking model which is more focus over contents rather than destinations. It also secures the contents itself instead of securing the communication links. In this model the contents are named based instead of IP addresses.

Different ICN proposals appeared after the first ICN proposal as TRIAD [4]. The current proposals which are highly focused by the both research and academic industry are Domain-Oriented Networking Architecture (DONA) [5], Named Data Networking (NDN) [6], Content Centric Networking (CCN) [7], Publish Subscribe Internet Routing Paradigm (PSIRP) [8] and Network of Information (NetInf) [9]. In-network cache mechanism is the common feature among all ICN naming proposals. In-network is an end-to-end network caching system in which every router node is capable to cache contents. End-to-end network caching reduces the traffic across multiple hops. ICN caches the delivered content first and then for every repeat request user get the requested data from the first hop. The popular contents cache more than the least used content. Requests usually send across network for unpopular contents.

In this paper, we have simulated a network scenario with cache at the network edge and end-to-end. We have made a comparative analysis for the performance of in-network over network edge caching system. The results show that in-network caching mechanism is much better then caching at the network edge. It gives more capacity to Wide Area Network (WAN) links, reduce congestion and avoid bottleneck which gives opportunities for real time and delay sensitive applications. The end-to-end network caching system allows applications to run efficiently in ameliorated traffic rate of traffic.

The next section describes caching at the network edge and in-network modes of the networking architectures. Section 3 explains the methodology including simulation setup and analysis for different network performance parameters. Section 4 accentuates the simulation results. Section 5 discusses the implications and challenges in the industry for information centric network. Section 6 concludes the paper.

II. NETWORK CACHE

Today, the Internet is playing a significance role in human life. Users are able get information and their desirable contents by using download. Online services such as music and video streaming, webinars and interactive learning sessions are playing major roles in augmenting network traffic. With the increase in utilization of these services, the performance and capacity of WAN links are becoming over-utilized. This is deteriorating users' experience and degrading the services quality due to exchange of high volume traffic in fixed bandwidth capacity. The augmentation in use of social networking also contributed major share for the distribution in sharing of pictures and videos. The video steaming tutorial videos are being accessed by people from various professions, distance learning allows people to watch and learn about their relevant knowledge anytime. The availability of Internet in most regions motivated the people to relying over this communication medium from their basic necessities of life to the online entertainment world. According to reports [10] and [11], 61% percent of population in Malaysia were using the Internet till 2011. This massive access data rate for content servers degrades the performance of network-based applications. Caching mechanisms are introduced to reduce the movement of traffic over the Internet. It diminishes requests and replies in end-to-end communication from server to the client. The low number of queries ameliorates server performance holding the applications.

A. Network Edge Cache

The Content Delivery Network (CDN) was introduced a solution towards the improvement in performance of servers during high access rates. The first CDN based system was AKAMAI [12] which give multilevel failover. The AKAMAI implemented in several sectors in U.S. which give high failover with protection against DDoS attacks as well. It also enhanced the performance of cloud based Software as a Service (SaaS) and increase file transfer rate by multiple factor due to caching at the edge. Internet Protocol Television (IPTV) is using the same CDN caching mechanisms. It is a preferred choice of Internet Service Provider (ISP) to reduce the traffic from their customer towards their connectivity links with other ISP peers. The Peer-to-Peer (P2P) systems use the same edge caching technique. ISP and P2P systems also use CDN techniques to optimize performance of data dissemination. Figure 1 presents the topology to define the network edge caching mechanism.

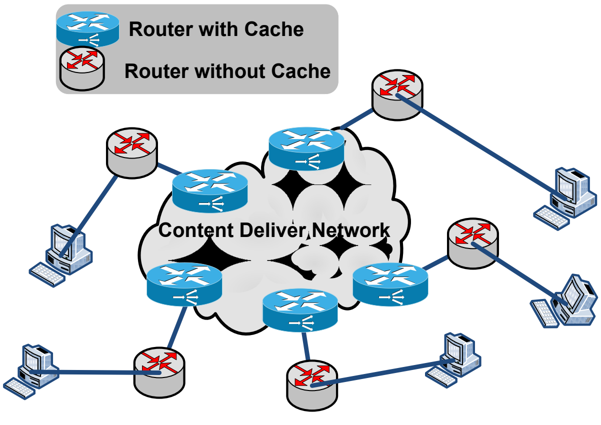

Fig. 1. Edge Network Cache

B. In-Network Cache

The ICN uses end-to-end caching mechanism. In end-to-end caching mechanism every router node caches data. The caching supports in reduction of hops for future requests for same data. It also decreases latency and delay. This gives opportunities to run other time sensitive real-time applications. It makes the same available network become more productive.

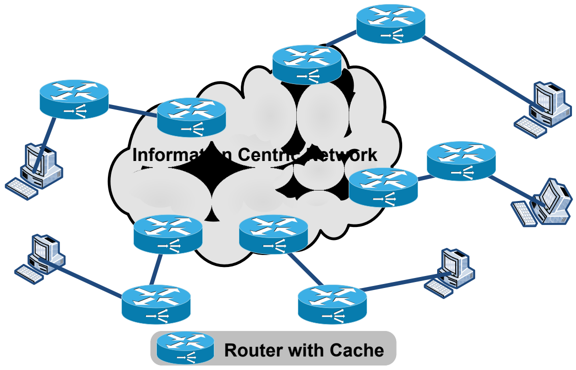

Fig. 2. In-Network Cache

The applications such as voice and video can be run more efficiently because of reduction in congestion and bottleneck across end-to-end network. The ICN models such as NDN, DONA and NetInf use end-to-end network caching while PSIRP uses both caching mechanisms; at the network edge and in-network cache. Traffic from ISP's neighbor peers also reduces which decrease the load over server and increase efficiency. Figure 2 shows the topology for end-to-end caching in the network.

III. SIMULATION SETUP

The network simulator ns3 was used to simulate both caching scenarios to analyze the results. We have simulated a same network topology for two different scenarios based on different techniques for network caching implementation. The simulation parameters are as shown in the **Table I**. In first simulation the network was simulated with the caching at the edge network in Fig. 3. Only edge network nodes were simulated with cache implementation. The router nodes C1, C2, C3 and C4 were simulated with cache, although the rest of simulated router nodes were not simulated with caching mechanism. We used this technique to represent and evaluate CDN results.

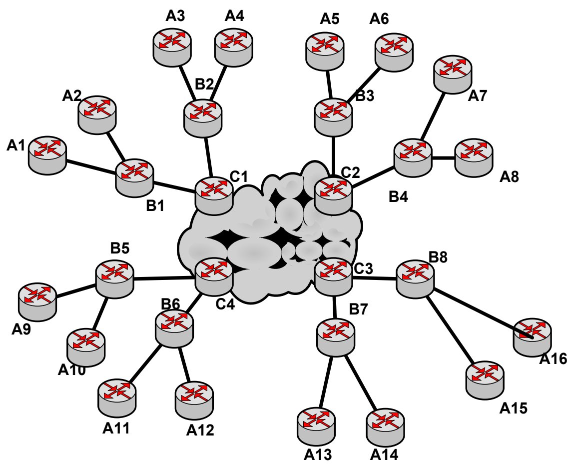

Fig. 3. Network Simulation Topology

In the second simulation we used the same network topology which was implemented in CDN. End to end caching mechanism was implemented in second simulation scenario. The in-network caching was used to depict ICN data dissemination performance in comparison to caching at the edge network. All router nodes in the network topology shown in Fig. 3 were simulated with in-network caching technique to analyze the impact on network performance.

TABLE I. SIMULATION PARAMETERS

Parameters	Value
Request	100/Second
Number of nodes	28
File Size	1024 KB
Simulation time	60 Seconds
Routing Strategy	Best Route

IV. METHODOLOGY

The network performance was evaluated for ICN and CDN caching to analyze cache hits and overall network traffic.

$$f(x_j) = \sum_{i=1}^{n} x_i / n \quad (1)$$

Where j is the time in seconds during simulation, i the events in one second throughout the network, x is the moving network traffic in an event and n is the total number of events in one second.

$$fc(x_{i,j}) = \sum_{j=1}^{60} \sum_{i=1}^{n} x_{i,j} \quad (2)$$

$$fi(x_{i,j}) = \sum_{j=1}^{60} \sum_{i=1}^{n} x_{i,j} \quad (3)$$

$$S_r = fc(x_{i,j}) / fi(x_{i,j}) * 100 \quad (4)$$

From Equation 2 and 3, $fc(x_{i,j})$ and $fi(x_{i,j})$ represent the results for overall moving network traffic throughout the network for CDN and ICN respectively,where j is the time in seconds during simulation, i is the events during each second, x is the moving network traffic during simulation.

In Equation 4, S_r is depicting the overall moving network traffic dramatically reduced by 71% of edge network cache in Fig. 5 due to in-network caching.

$$fc(C_{i,j}) = \sum_{j=1}^{60} \sum_{i=1}^{n} C_{i,j} \quad (5)$$

$$fi(C_{i,j}) = \sum_{j=1}^{60} \sum_{i=1}^{n} C_{i,j} \quad (6)$$

$$S_r = fc(x_{i,j}) / fi(x_{i,j}) * 100 \quad (7)$$

In Equation 5 and 6, $fc(C_{i,j})$ and $fi(C_{i,j})$ represent the results of overall cache hits throughout the network for CDN and ICN respectively, where j is the time (in seconds) during simulation, i is the event during each second, C is the number of cache hits during simulation.

In Equation 7, S_r is representing the success rate of edge network cache hits compared to in-network cache was only 3% of cache hits in in-network during 60 seconds of simulation.

$$f(C_j) = \sum_{i=1}^{n} C_i / n \quad (8)$$

V. RESULTS

Figure 4 shows the network traffic throughout the designed topology for ICN and CDN simulated network. Results are representing the prominent difference in improvement for link utilization. The graph to calculate overall moving network traffic during simulation in Fig. 4 is drawn for the overall moving network traffic using the Equation 1. Figure 4 is showing data responses against requests for the contents which were obtained via first or second hop in network topology. The result in Fig. 5 is showing the cache hits during simulation. In a hierarchical way router nodes are able to get more data from their neighboring peers. The data which is requested earlier by the other router nodes is cached for future requests.

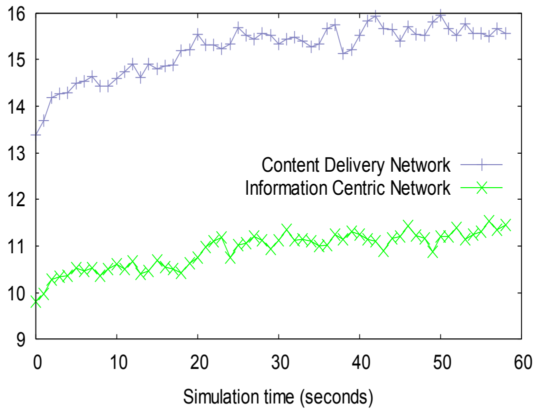

Fig. 4. Overall Network Traffic

The Fig. 5 graph obtained using the Equation 8. Where j is the time in seconds during simulation, i the events in one second throughout the network, C the cache hits in an event and n is the total number of events in one second.

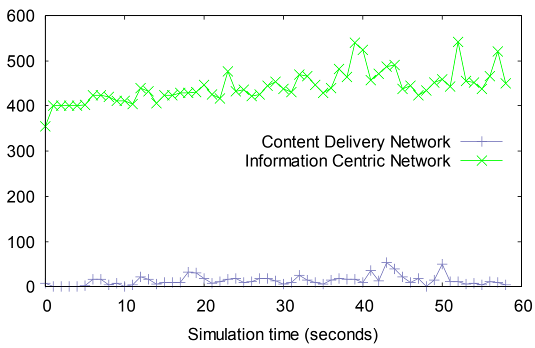

Fig. 5. The ICN and CDN Cache Hits

The graph in Fig. 4 is accentuating the overall moving traffic in the network was reduced when requests for contents were met by the cache in Fig. 5. This result is with lower moving traffic load at WAN communication links. The reduction of congestion in communication links leads to improvement in quality of network services. The removal of bottleneck in the network would provide more opportunities for other applications and services to use the same links capacity. Removal of congestion and bottleneck is result of diminishing delays. The delays sensitive applications such as real-time applications can improve tremendously.

VI. Discussions

The implications of ICN platform are highly beneficial for different industrial sectors in Malaysia such as agriculture, palm oil and rubber, disaster situations, healthcare, electrical & electronics and education. Farmers and other roles in agriculture sector are very important. This industry is directly connected to human beings' basic requirements. The motivation for the use of emerging network technology in agriculture would produce better positive results for informational contents. In Malaysia, to develop and improve agriculture industry the information disseminates by magazines to the pertaining people. Radio channels, newspapers and Television (TV) are also playing roles in the information dissemination among farmers [13]. This information is subjected to the availability of print media in rural areas to the farmers. Distribution of information using print media involves additional cost. The network infrastructure for mobile communication is available throughout Malaysia. The ICN is promising for the solution of massive growth of contents [14]. The ICN is a content specialized networking architecture. It can improve the content dissemination mechanism greatly. The information can spread across farmers using ICN would reduce the cost of print media. Moreover, it will remove the timing constraints to for specific time information from radio and TV media. Farmers can get information at any time when they want to improve the agriculture industry. In Malaysian agriculture industry, palm oil is one of the major exporting agriculture products [15].

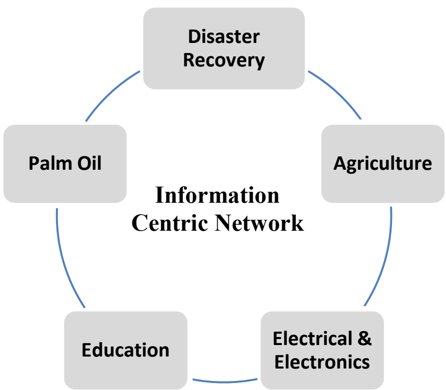

Fig. 6. ICN Industrial Implications

ICN in comparison to CDN consume less energy [16]. It would motivate the electrical and electronic industry for green technology. ICN promote the ease of content dissemination in quicker time and produce much better link utilization for contents and applications.

ICN is promising for emergency scenarios in the absence of infrastructure devices. It allows reserving the last available contents as cache among the available router nodes during disaster. The ICN implementation would enable the essential content delivery requirements in emergency situations during catastrophe [17]. In healthcare industry, patient information records are highly confidential. The information centric network does not only offer cache mechanism to boost the access but also provide content encryption instead of securing the communication link. The security of content itself will also reduce the conventional security devices cost.

Education contents are usually not real-time. These contents are available to access anytime. Without the support of infrastructure ICN would enable in continuing the education content easily accessible. It would reduce the bandwidth cost and would produce more productive life.

VII. Conclusions And Future Work

The ICN architecture is a solution towards the enormous growth of contents over the Internet. It allows the efficient delivery of contents in a network. In this paper, we focused on caching feature of ICN which is promising for adaptive content distribution using in-network caching approach. The simulation was used to evaluate the impact of in-network and network edge caching of overall moving traffic over the network. It was observed that it reduced the moving network traffic which diminishes network congestion. The reduction of network traffic over WAN communication links can dramatically improve the utilization of links capacity. The edge routers will be able to utilize the same available bandwidth to receive and transmit more contents. The ICN can give productive results to improve different industrial sectors including agriculture, electrical & electronic, disaster management and education. Our future work will be to enhance the ICN architectural components to spread economic benefits across industrial sectors.

Acknowledgement

This research work is funded under the Ministry of Higher Education Malaysia's Long-Term Research Grant (LRGS) with reference number LRGS/TD/2011/UKM/ICT/02/02(2).

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