A Brief Introduction to Content Centric Networks

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***Abstract*—Currently, scalable network architectures are constantly growing, so, applications related to the Internet have grown exponentially, which produces a large amount of data that is heterogeneous in a context where all the actors under the Internet of Things, Big Data, and Machine Learning context are interconnecting. However, this excess of information generated by social networks has become a relevant problem, since service providers send large volumes of additional content and advertisements to their clients. This event, in turn, worries customers as it decreases the likelihood of being able to read these messages, resulting in overloading the data network and causing network congestion. Accurate content management requiring to manage this problem. Undoubtedly, the concern is to provide accurate information to the user and manage large volumes of user information and content. Thus, content-centric networks must allow access requirements to be met, as well as content delivery. This type of networking uses data names instead of host names and allows caching in network management. The CCN uses a transmission method to deliver the content request in the form of a packet. The main reason for this article is the network focused on content, its way of managing content, and the strategies that exist to address the problem raised above.**

I. INTRODUCTION

Currently, large-scale networks have been immersed in the management of large amounts of data and content due to the use made by users of social networks, including Facebook, YouTube, Twitter, and Google, which has allowed for the expansion of human social interaction. Similarly, users having access to this varied volume of information instantly causes data network architectures to collapse due to data congestion in the network. On the other hand, service providers recommend making use of different types of content and advertisements for their respective users [1]. In turn, as there is an overload of content on the network, which is not used by users, this causes a part of this information to be discarded, which remains wandering on the network and is what generates bottlenecks in the net. Therefore, this situation causes the profits of the providers to decrease because users do not see the ads, which are the main source of income for these social network providers. In this same direction, a new methodology is required that objectively allows distributing the context space to the content space. However, the context space is the time that the user uses to carry out personalized recommendations. The inconvenience arises when these users must manage large volumes of heterogeneous data that are constantly growing. In [2], content-centric networks (CCN) are proposed, which were initially proposed to solve the communication problems at the existing Internet protocol (IP) level, thus changing entirely to a content network architecture. In [30] traditional network architectures made up of IP addresses, addressing is assigned to the node and interfaces, unlike content addressing in CCN, in which they are assigned a unique and rootable name. The foundation of this type of network lies in the fact that clients observe the type of content, instead of observing which direction the data takes and where the data packets go in the network topology.

However, content-centric networks have network topologies that manage various types of content on the Internet, so that data packets are routed through various routes in the network structure, thus allowing them to arrive with the packet of data to a destination node. Thus, the communication channels between endpoints consist of data with names that replace conventional IP addresses. Similarly, each of these data packets is made up of a segment of requests and return of content. Likewise, one of the primary functions of CCN is to provide flexible, protected, and scalable services to establish secure data deliveries, in conjunction with end devices, on a large scale. If the provider can guarantee secure and named content in distributed capture, then automation in the content on demand can take place. If there is a named request, the content network architecture delivers named content to the client with the shortest network path and least network hop available, thus ensuring that you do not have to manage redundant requests by helping to consume fewer network resources. Therefore, the CCN, the named content format is used as a packet address instead of a node identifier, which allows the network not to be overloaded with data and allows better energy consumption refers unlike data networks based on IP addresses [3].

On the other hand, the use of CCN to establish social activities online using the various types of social networks allows the dissemination and retrieval of content in the establishment of one-to-many and many-to-many relationships, which helps service providers to obtain a specific context from the client, thus allowing them to provide accurate content to the consumer [4].

In this same direction, the development of social networks has not been the most satisfactory in the context of Big Data [5]. However, when you have a minimum set of data, it is advisable to calculate the operations for each of the data individually, thus obtaining more accurate results. Thus, to the extent that processing increases in the volume of large amounts of data, this generates a high computational cost and hinders performance in the use of algorithms [6]. In the same way, all the contents are grouped and organized in data structures in the form of a tree to be able to achieve high-performance operations, where the construction process of the tree is separated from the operations, which generates difficulties to function satisfactorily [7].

After the Introduction, section 2, Related Works, outlines the main works related to content-centric networks. In section 3, content-centric networks are outlined and in section 4, some strategies related to content-centric networks are proposed. In section 5, some applications used with content-centric networks are discussed. In section 6, the conclusions of the work in question are presented.

II. Related work

The content-centric network gives rise to other network names such as the data-oriented network, the name-centric network architecture, the information-related network structure, the publication-oriented network architecture, and subscription, which orienting to the delivery of data instead of focusing on the node [8]. The important thing about all these generations of networks is being able to become familiar with the evolution of these architectures. All these network structures differ in terms of implementation, but they have in common, the ability to improve performance and user experiences using the Internet by presenting them with access to content and services classified by name instead of giving them the location original. All these architectures relating based on parameters related to naming schemes, security, name resolution, network caching, and transport, etc.

Content-centric networks with respect to sensor data present a different transmission protocol. Therefore, CCN are complete architectures that are executed as a conglomeration of essential pieces in a network layer. In turn, intermediate message servers are not required in CCNs because their clients have a variety of data that they can request by issuing a message of interest that allows them to describe this data. Content-centric networks do not reference the location of data, these can be present in the origin node or in the path that goes to the origin node [9]. Similarly, in the context of the Internet of Things, the use of content-centric networks presents some advantages, which are:

- Connections between nodes are not required.
- Network caching is available and transparent.
- Using sensor technologies help manage network caching.
- The workload level of sensor devices decreases.
- Through the structuring of an abstraction layer, sensor technology can be accessed.

On the other hand, the disadvantages obtained from using CCN with the Internet of Things are:

- Resources are wasted on sending content.
- By requiring more computational power to execute certain types of operations, it is more complex.

In [10], a study of network caching strategies in information-centric networks was presented, where contributions, constraints, and performance evaluating in terms of cache hits, expansion rates, and eviction operations. In addition, it proposes that to improve the performance of *n* information network architectures with respect to the previous parameters, it is necessary to eliminate content redundancy, reduce the jump and delay of fetching content between node and node. Thus, in addition, there are some unresolved challenges in the use of ICN networks, related to the type of traffic and caching space, in which, the duplicity and redundancy of content is closely related to this type of network.

Therefore, CCN networks reflect the evolution of traditional network architectures, such as Internet IP networks, due to their caching within the network. In [11] a model to evaluate energy consumption is presented and a caching system within the network is proposed, thus allowing energy consumption to be optimized. In turn, a cache replacement approach constituted by neighbor collaboration is proposed that uses the cache resource of the neighbor node and that allows improving the possibility of which content is cached and thus allows achieving the use of resources. Also, a comparison is made with the existing system in terms of high data transfer, which allows to improve the general performance of the caching network and generates energy savings for a better distribution of the contents in the network.

III. Content centered networks

Communication in this type of networks is carried out at the level of nodes that receive the data packets in the network architecture, which are made up of various clients through which they exchange data in the form of packets, which are combined data packages. In general, these packages are made up of a name that is different from the locality information. Therefore, the main function of these packets is to uniquely identify the content or a segment of that content that is transmitted in a data packet. In turn, customers who request specific content communicate their interest through the connections that are available at the time. In turn, at the node level, these are made up of data structures that respond to client requests using data packets. In this sense, the interest and data packets help these nodes to exchange data by making use of content identifiers, so that a cluster of nodes may have an interest in the content that another node is using the exchange of these contents is carried out through a physical means of communication.

It is important to mention that a content can be made up of several pieces of data. Thus, the content uniquely identifies any part of this content in which the location information is independent of the content. Likewise, communication of content is carried out using these names. Terms that refer to data or content are called content objects in a CCN [19].

Apart from the two packets mentioned above, there are three data structures in each node that allow data packet forwarding tasks to be carried out properly. In Fig. 1, we can observe the components of a CCN.

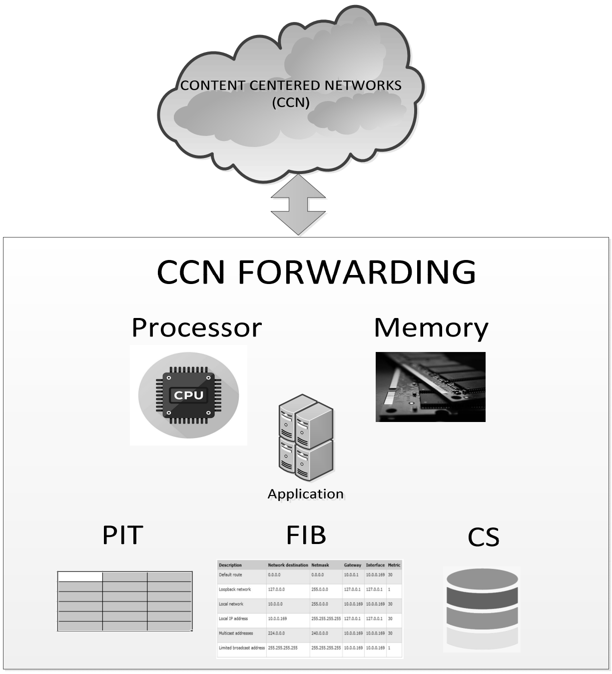

Fig. 1. Architecture of the components of a content-centric network

The three data structures are explained below. These are:

- **Pending Interest Table (PIT)**: It is a table in which information of the data of interest is stored together with the data contents and the input and output devices. The pending interest table is considered data, like a hash table, where each input to the PIT points to the sources.
- **Forwarding Information Base (FIB)**: With this information, which resides in these tables, packets of interest are forwarded to the destination node in network topology, in which there may be matching data. The FIB is made up of a list of outgoing data instead of a single data. CCN allow access to multiple data sources and can be searchable in parallel.
- **Content Store (CS):** Used for storing data packets on the network, not indefinitely. The content store has implemented a replacement policy, which consists of using the least recent data (LRU) to increase the possibilities of data reuse.

It is important to mention that the retrieval of content in a CCN begins with the various requests from clients. In the network, there are messages of interest which are forwarded in the network according to the requests sent by users. However, the switch that receives the packet of interest proceeds to check it to see if there are matches with other data packets. In case there are no matches, the router finds the name in the PIT and appends it to the entry in the corresponding PIT. Furthermore, if the interest is not located in the PIT, the FIB is used to decide the next hop where to send the next interest.

On the other hand, when you have the content object, you proceed to verify the PIT to confirm the corresponding entry. If an entry in the respective PIT does not match, the router takes the packet of interest and passes it to the content store using information stored in the FIB. Thus, the content is sent to all nodes with their respective links in the PIT. In turn, the required content is delivered in response to the respective packet of interest, moving in the opposite direction to the packet of interest. In this reverse process, each router in the CCN removes the entry related to its respective PIT.

IV. Caching Network Strategies in the Face of Information Excess

In the field of content-centric networks, these are conceived as a large-scale network structure aimed at meeting the requirements related to access and delivery of content. Thus, there is a cache where a variety of copies of the data are stored. In this case, content-centric networks using node-level caching allow for better network performance and efficiency. There is a variety of novel cache storage strategies that have been proposed as strategies to improve the performance of content-centric networks [12].

These cache storage strategies are mentioned below.

- **Leave Copy Everywhere (LCE):** Used as a parameter that helps in the process of capturing the data messages. However, each node contains a data message which is used by each node for what has happened. As there is an availability of this data in each node, a redundancy of content is obtained as a result.
- **Leave Copy Down (LCD)**: It is used as caching for data detection on the network, so the data is copied between the active nodes, taking into consideration the sending node of the information [13].
- **Probabilistic in-network caching (ProbCache):** It is used as a cache for the distribution of content on the network from an established route on the network. Thus, the best node to cache content along this caching path is chosen and content is allocated evenly across a shared path [14]. One of the main objectives of this algorithm structure is to reduce redundancy in caching, as well as to make efficient use of the network infrastructure.
- **Max-Gain in Network Caching (MAGIC):** Used as caching allows it to be used to increment and add new content sections. This allows to improve the bandwidth of the network by reducing the redundancy and the routes through a given path between nodes in the network [15].
- **Cache Less for More**: The central idea is that if a specific node is part of several content delivery paths, then there is a probability that this node is considered to contain content [16].

In the following, Table I, a comparison is made between the cache storage strategies.

TABLE I. COMPARISON BETWEEN CACHE STORAGE STRATEGIES

Cache Storage Strategies	Advantage	Disadvantages
Leave Copy Everywhere (LCE)	High data availability.	High redundancy in the contents.
Leave Copy Down (LCD)	There is no duplication of data.	Low diversity in data format.
Probabilistic in network Caching (ProbCache)	Makes efficient use of available cached resource utilization.	Low diversity in content.
Max-Gain in Network Caching (MAGIC)	Helps reduce bandwidth consumption.	Very expensive computational cost.
Cache Less for More	- Good strategy for cache storage strategies. - Low cost in computational complexity. - High diversity.	Greater travel in the routes towards the contents.

As there is no standardized reference framework to be able to evaluate and compare caching strategies, it has been decided to use various instruments such as simulators, environments, and parameters, etc. Given this situation, we have selected four parameters from the literature that are applied to different simulation environments, which are:

- **Topologies:** These network topologies are built from tree-like data structures called k-aries, which help evaluate network caching strategies. In [14] binary trees of 6 levels are used (for a total of 127 nodes), in which requests that are issued from lower parts of the data structure are served by the root node. In [16] and [15] the same type of tree data structure called k-aries is used, where the priority levels go from level 4 to 6 and the number of children per node varies between 2 and 5. In [20] a hybrid topology composed of ISP-type topologies and a binary tree structure composed of five levels is modelled. Other types of network topologies, such as GEANT, Level3, Tiger and GEANT are considered in [21] and [22], based on ISP-type network topologies. The same happens with the network topology, Torus, which is considered by the authors in [23], using ISP-type network topology [24] from the services generated by the RocketFuel network topology, other network topologies are generated at the ISP level called AS1755 (eBone), AS3967 (Exodus). Similarly, the GEANT network structure are considered in [23], [25]. In Fig. 2, we can observe the simulation of the topologies parameter from some of these network topologies mentioned before.
- **Content Popularity Model:** It is a function that allows measuring the popularity of each content, that is, how often customers request each content. The authors in [26] and [21], use the Zipf probability distribution function (α) for modeling. The range of values for Zipf (α) varies between 0.6 to 2.5. In the case of the Pirate Bay catalog, the parameter α = 0.75 is used and in the Daily Motion with α = 0.88 and VoD in China has an α value between 0.65 and 1.0 [27]. In this other case, a popularity model, Zipf (α), with a value of α = 0.8, [14] is used. In [16] we have that this parameter is α =1.0. In [25] it ranges between 0.6 and 1.1. In [23] and [21], α is between the values of 0.65 and 2.5. The authors in [24], use the value of α is between 0.7 and 0.96. In turn, in [15] the value of α is between 0.7 and 1.1. In [20] the authors evaluate caches with snippets pulled from Akamai CDN Asia. Traces from wdklife.com are used in [28] as a Chinese training source.

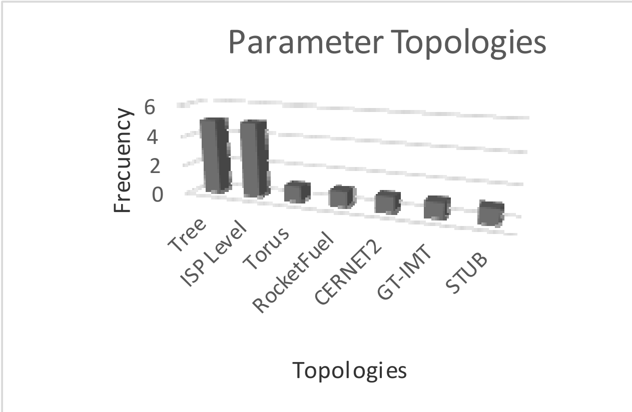

Fig. 2. Parameter Topologies

In Fig. 3, we can see the simulation of the Content Popularity Model parameter from the Zipf(α) function.

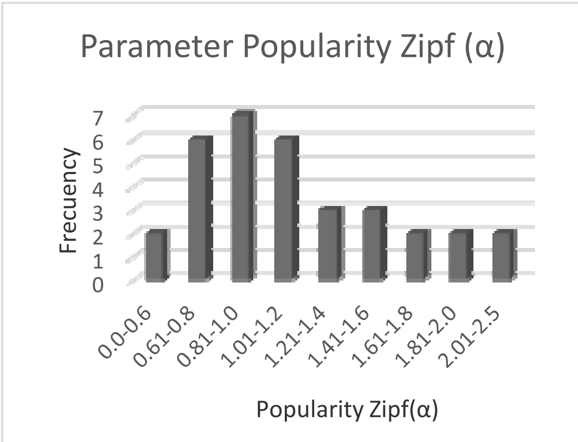

Fig. 3. Popularity parameter of each content, Zipf (α)

- **Catalog:** Represents the total of the collection of elements that are made up of the contents of the network. As there are several requests regarding a specific content, this will be determined by the model used with this content. In turn, the size of the catalog will be directly related to the content that exists on the network. For example, the authors in [23], [21] and [22] consider a content catalog called YouTube made up of 108 pieces and in [15] they consider another content catalog of 104 pieces. In [28] a catalog of 104 pieces with a weight of 8 MB is used. In [16] he uses a catalog of 103 pieces. In [7], [10], and [15] the dimension of the catalog is not detailed, but the generation for entire catalog is of 105 requests. In [14], the size of the catalog is not detailed either.

In Fig. 4, we can observe the simulation of the Catalog parameter based on the number of content pieces.

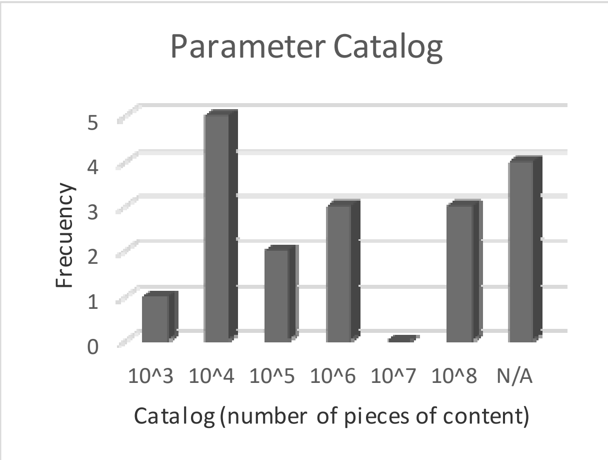

Fig. 4. Content Catalog parameter

- **Cache Size:** Determines the space available in each node of the content-centric network to store pieces of content temporarily. These portions of content have a relationship at the level of absolute value according to the dimensions of the catalog. Thus, the cache is made up of elements that have certain proportions, for example, 105 elements with dimensions of 2 x 102. In [25] values between 0.2 and in [16] with a value of 0.1 are used. The authors in [24] use values that are between 0.01 and 0.06, while the authors in [15] suggest using values between 0.005 and 0.005. Therefore, in [21] the authors take into consideration the differences that occur in the size of the cache and the content of the catalog. In Fig. 5, we can observe the simulation of the Cache Size parameter from the cache size of the contents.

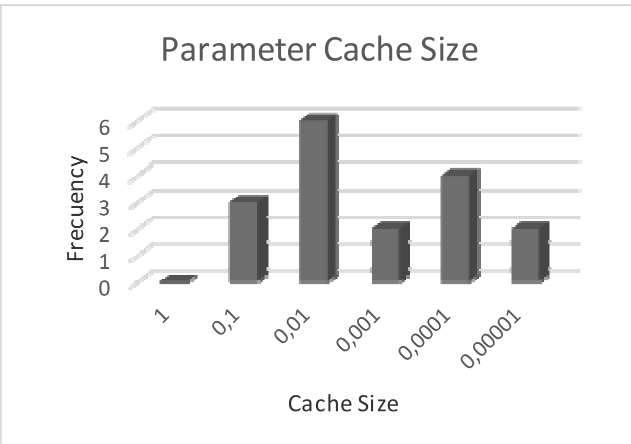

Fig. 5. Cache Size parameter

In Table II, a comparison between the parameters is presented.

TABLA II. FOUR PARAMETERS USING IN THE DIVERSE SIMULATION ENVIRONMENT

Parameters	Values
Topologies	ISP (Tree, ISPLevel, Torus, RocketFuel, CERNET2, GT-IMT, STUB)
Popularity (Zipf (α)	MZipf (α = {0.65;1.1;1.5;2.0}, β = 0
Catalog	C = {$10^{3;}$ 10^4;10^5;10^6;10^7;10^8; N/A}
Cache Size	CS = {10^{-6};10-^{5};10-^{4};10^{-3}}

V. ENFORCEMENT OF CONTENT-CENTRIC NETWORKS (CCN)

According to the authors in [17], a series of applications in the CCN are presented, which are:

- **Medical devices and healthcare management systems**, where medical care markets are growing because of personal well-being and remote health control, accumulate, and distribute various types of data on individual medical care. In turn, applications located at the server level have faced challenges of security and confidentiality, the connection of heterogeneous devices, and information gathering and sharing. Thus, there are requirements for a secure communication platform to access, accumulate and distribute healthcare data. Content-centric network architectures allow medical teams to securely access and share content with deployed infrastructure or back-end architecture systems. By using data-centric cryptographic techniques in content-centric networks, patient health and wellness data are shared securely [18].
- **A Safe and cost-efficient lighting control system** allows lighting systems to gradually change towards energy-efficient options, such as light emitting diodes (LED). Similarly, lighting control systems use an IP-based infrastructure, resulting in a solution that involves high costs and inefficiency. The implementation of firewalls is required for the protection and allocation of IP addresses. However, a CCN architecture provides a model that is safe, cost-effective and has strong lighting control.

Content-centric networks have a reference to information-centric networks, so we take this last network architecture as a reference as an IoT paradigm, we can have applications in [29] vehicular ad hoc network topologies, wireless sensor networks, mobile ad hoc networks, smart grids, etc., each of these network structures with its own characteristics and needs.

VI. CONCLUSION

The Internet provided by Internet Providers (ISP) is efficient for host-to-host communication, but not for the distribution of data and content through an IP, public or private, in a network architecture that is growing exponentially and dynamic and that is on a large scale. Therefore, content-centric networks (CCN) emerge as an innovative approach to the next generation of the Internet, such as IP version, 6. These architectures invoke CCN to account for multiple replications of information, which creates a lot of redundancy once that data is replicated multiple times.

Under the circumstance of abundant redundancy, a network-centric, content-oriented caching network architecture is proposed, which avoids the overload of data packets in the network and saves the data load in the network. It is determined that a caching strategy called MAGIC outperforms other proposed strategies in terms of access and caching. The most sensible approach is to choose policies according to the goals of content-centric network architecture; therefore, the recommendation mechanism is integrated with CCN, which is a necessary requirement in the context of computer networks.

Also, to evaluate and measure these caching strategies, a series of parameters related to the topology of the network, therefore, a series of parameters are used to evaluate the strategies at the caching level, which allows improving the performance of the network and reducing the level of redundancy, which prevents the network from becoming congested. The use of these four parameters used in various simulation environments allows us to determine how efficient caching strategies can be when managing the abundance of data that exists in the network topology and that normally overloads the information network.

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