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Energy Efficient Content Dissemination Architecture for Content Centric Network

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Abstract: Nowadays the Content Centric Networking (CCN) has gained much attention of research interest due to its content-based behavior. CCN seems to be an alternative to the IP-based networking, since, it replaces the host-to-host routing by name-based-routing. In this study, a new energy efficient content dissemination architecture has proposed for CCN to achieve its services such as content dissemination, content caching and managing trust only by the name of content.

Key words: Content Centric Networking (CCN), host-to-host, CCN node model, energy, services, dissemination

INTRODUCTION

The Future Internet (FI) depends on flexible end-to-end content distribution and retrieval as per the user's need. The current IP-based network focuses on the host-based architecture, i.e., content dissemination is done by the address of the host (host-to-host routing) but a typical user does not care about the address of the host, since, he/she can get the internet services through a trusted third party (e.g., Google). The interest of a consumer is usually limited to the identity of the content ('what' should be accessed) instead of the identity of the content provider (from 'where' it should be accessed). Moreover, today's IP-based networking suffers from a number of limitations such as excessive bandwidth cost due to CDNs and P2P network, location dependency, persistence of naming, lookup delay due to DNS server, critical security issues due to name-to-address translation (Detti and Blefari-Melazzi, 2011; Jacobson *et al*., 2009; Koponen *et al*., 2007). CCN can be thought of as a replacement to overcome these limitations as it provides location-independent naming of contents. In CCN, security measures travel with the content, so, the user can easily validate the content even if it comes from an untrusted content provider. In this study, the proposed architecture is considered as a collection of several rendezvous-based nodes connected to a number of advertise-based nodes to make it energy efficient (Detti and Blefari-Melazzi, 2011). By Braun and Trinh (2013), some energy efficiency issues have been highlighted. Our concentration is to establish a path for flexible end-to-end communication in CCN based on the content name itself where the target location is completely unknown. Once, the path is established, the sender and receiver can communicate with each-other based on that pre-established path. Also, incase of content retrieval, path establishment is necessary between the consumer and the content provider. In both the cases, trust management is also, necessary to ensure that both the parties involved in message passing are authentic.

Literature review: The main goal behind the CCN is to decouple the content or data from their source and to replicate (or cache) them throughout the network so, that they can be addressed directly, rather, than their providers with a reduced bandwidth consumption. Recently, several architectures have been proposed to achieve this goal. By Detti and Blefari-Melazzi (2011), several issues have been discussed by comparing CCN with traditional IP based networking. DONA (Koponen *et al*., 2007) describes a flat, self-certifying name-based anycast primitive for resource-discovery. By Jacobson *et al*. (2009), a CCN (also, known as Named Data networking (Zhang *et al*., 2010)) has been proposed based on two different packet types-interest and data. A hierarchical naming scheme has been provided by Zhang *et al*. (2010) to represent the context and relationship of data elements. By Ko *et al*. (2012), the

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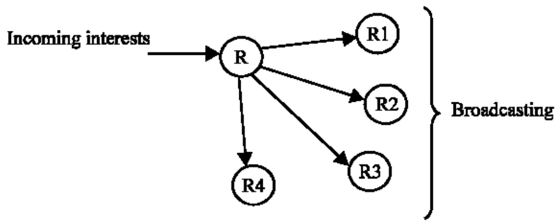

Fig. 1: Broadcasting of incoming interest

proposed IC-DCN describes a label-based forwarding technique based on the centralized control plane and distributed data plane. An SDN based routing scheme for CCN is proposed by Aubry *et al*. (2015) where a large network is divided into a number of smaller networks and each of the smaller network is managed by a controller.

In this study, we have focused on the CCN architecture proposed by Jacobson *et al*. (2009) and on the SDN based routing scheme proposed by Aubry *et al*. (2015).

MATERIALS AND METHODS

Proposed CCN node model: In this study, we have discussed sevaral issues related to CCN architecture and accordingly proposed efficient solution with proper justification.

Energey efficiency: In case of content retrieval, upon receiving an incoming interest from the consumer by a particular node, that interest is broadcasted to all the adjacent nodes connected to it (Jacobson *et al*., 2009). This may cause lack of energy efficiency. For example in Fig. 1 suppose node R receives an incoming interest for the content/image.jpg and it is not in the cache (content miss) associated with R. Node R broadcasts the incoming interest to all the neighbor nodes connected to it and updates its Pending Interest Table (PIT). We assume that node R_3 hears that interest (content hit) and delivers the content to R following the reverse path. Now, node R updates its Forwarding Table (FIB) and caches the content into the associated content store. Based on these processing steps as by Jacobson *et al*. (2009), we assume that:

- E_1 = Energy costs for receiving an incoming interest
- E_2 = Energy costs for forwarding an interest over a singl link
- E_3 = Energy costs for content retrieval and delivery

Therefore, the total energy = $E_1+4E_2+E_3$. However, out of this total energy only $(E_1+E_2+E_3)$ is actually in use. Therefore, $3E_2$ amount of energy is totally wasted for serving a particular interest.

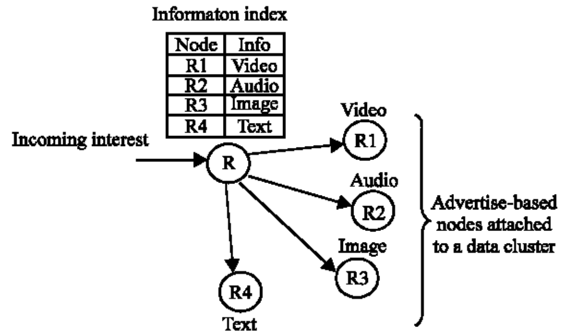

Fig. 2: Rendezvous node R connected to 4 advertise-based nodes

We propose this overall arrangement as a collection of rendezvous-based nodes attached to a number of advertise-based nodes. The consumer requests its interest to the nearest rendezvous-based node. Each advertise-based node may be associated with a number of content servers. Each of the content servers can be considered as a cluster (closely related data) for effective utilization (Fox *et al*., 1997). For example in Fig. 2, R_1 may be associated with a content server of video data, R_2 may be associated with a content server of audio data. The advertise-based node advertises the information of the content server attached to it. This information is shared between the rendezvous-based node and the advertise-based node in a secure manner and kept into an information index maintained by the rendezvous node.

Upon receiving an incoming interest from the consumer, the rendezvous-based node searches its information index for a match. If any match is found, the interest is forwarded to that particular advertise-based node (unicast) and in that case, the content retrieval is possible. If not, the interest is forwarded to the immediate next rendezvous node from the present node and overall process will be repeated until content retrieval is done.

Now, let the additional energy costs for maintaining the index is E. Therefore, the total energy for serving a particular interest is $(E_1+E_2+E_3+E)$. So, the architecture should be designed in such a way to make it energy efficient that satisfies $E<3E_2$ (Braun and Trinh, 2013).

RESULTS AND DISCUSSION

Architecture: In this sub-section, the CCN node model (Fig. 3). Since, it is very hard to locate content in a timely manner because the size of the network is very large, we split the overall network into a number of

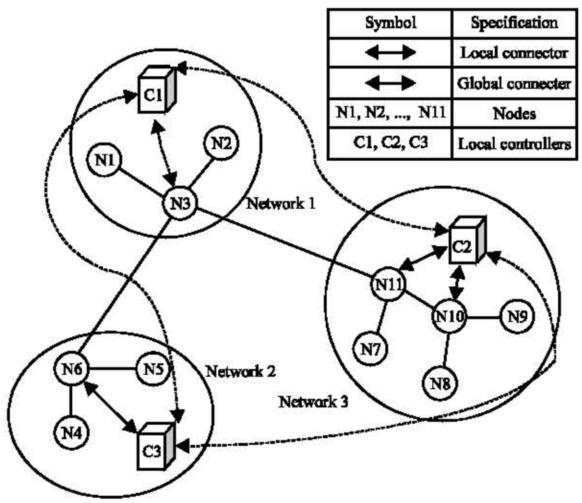

Fig. 3: Proposed CCN node model

sub-networks and associate a local network controller with each of them (Aubry *et al*., 2015). Each controller maintains the information about the rendezvous nodes of its local sub-network as well as the knowledge about the controllers of other sub-networks. Those nodes within a particular sub-network are considered as rendezvous nodes which have a degree centrality (Guan *et al*., 2012) of greater than one and not a terminal node. Such as in Fig. 3, both N_{11} and N_{10} of the sub-network-2 are the rendezvous nodes because they have a degree centrality of greater than one and both of them are not terminal nodes. We assume that the actual content servers and the consumers only can be located at the terminal nodes and the content caches (or content stores for storing content replicas) are placed on the rendezvous nodes instead of all the nodes by Jacobson *et al*. (2009) and thus, reduction in use of too many caches in CCN.

Content dissemination: In CCN, content routing and transporting is a crucial task. We propose an efficient content dissemination scheme based on the architecture as shown in Fig. 3. Any node, after receiving the interest for a particular content from the consumer forwards the interest to the immediate rendezvous node attached to it. The rendezvous node searches its cache and the information index of all the advertise-based nodes associated with it and (suppose) finds a miss. Then the interest is forwarded to the local controller from the current rendezvous node. The controller (upon receiving the interest) immediately forwards the incoming interest to all the other rendezvous nodes of its local sub-network as well as the other remote controllers of different sub-networks and waiting for a response. The remote controllers also, forward the interest to all the rendezvous nodes of their own network and waiting for a reply. Now, globally, all the rendezvous nodes have the same interest to serve. If any node finds a match, it immediately replies to its local controller specifying its identity. If multiple nodes within a sub-network find a match and reply to their local controller, then the associated controller computes the closeness centrality (Guan *et al*., 2012) of those nodes with the source sub-network and picks the least one. The controller immediately sends a reply specifying its identity to the other controllers as well as the source controller (if the current controller is in a remote sub-network) from where the actual interest comes in and stops its searching procedure. Upon receiving the reply all the controllers immediately stop their searching procedure except the source controller knowing that the interest has already been served. The source controller sends the information about the remote sub-network as well as the location of the content to the rendezvous node from where it gets the interest for that particular content. Once, the current node has the information about the location of that particular content, it finds the shortest path towards that location. After establishing a path, the content is transported by following that path in reverse order. During this content dissemination process the rendezvous nodes maintain three data structures-the CS (content storage), PIT and FIB and the terminal nodes maintain two data structures PIT and FIB. All these three data structures work exactly same manner as explained by Jacobson *et al*. (2009).

Content caching: For faster content retrieval in a CCN, content caching in the intermediate nodes is a necessary task. When the content is transported to the requester following the reverse path, all the intermediate (rendezvous) nodes store the copy (or replica) of that content which is referred as content caching (Detti and Blefari-Melazzi, 2011; Jacobson *et al*., 2009). During this process a popularity count for a particular content is initiated based on the number of requests for that content (Bernardini *et al*., 2013). Once, the popularity count reaches a pre-defined threshold it will be considered as popular. The node holding that particular content, after finding that it is popular, will inform the other adjacent nodes to cache that content to achieve a high hit ratio. In our CCN node model, we propose this content caching scheme only for the rendezvous nodes instead of all the nodes because the incoming interest is always forwarded to the rendezvous nodes whether the underlying sub-network is local or global and thus, reducing the number of caches used in CCN.

Managing trust: Content security in CCN becomes a central issue, since, contents can be accessed from anywhere regardless of their providers. The underlying architecture deals with decoupling of data from its source and replicating it into several content stores placed throughout the network in order to reduce overall bandwidth (Wood and Uzun, 2014). To achieve secure end-to-end content dissemination, a consumer must need to asses that the received content is the valid one and comes, without any alteration, from an authenticate provider (Ghali *et al.*, 2014; Smetters and Jacobson, 2009). A secure key agreement scheme or Internet Key Exchange (IKE) protocol may be used to successfully obtain these parameters (Diffie and Hellman, 1976; Nagalakshmi and Rameshbabu, 2007; Nagalakshm *et al.*, 2011; Cheng, 2001; Forouzan and Mukhopadhyay, 2013; Ray *et al.*, 2012; Goergen *et al.*, 2013).

CONCLUSION

In this study, an energy efficient architecture for CCN is presented. The proposed architecture is suitable for energy efficient end-to-end content dissemination, content caching and managing trust in CCN. In future, researchers will focus to develop node to node secure communication protocol to achieve better security for managing trust in CCN.

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