A New Content Location and Data Retrieval Algorithm for Peer to Peer in Smart Microgrids

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Extended Abstract

Microgrid is a low voltage distributed network formed by various distributed energy resources (DERs) consisting of a variety of loads, microsources (MS), energy storages systems (SS), and plugin hybrid electric vehicles (PHEVs) [1-3]. Microgrids have emerged as a powerful, resilient and sustainable power grid by incorporating advanced renewable energy systems for power generation [4-5] that can integrate and manage large amount of distributed energy resources in real time [6]. Microgrids can operate in grid-connected mode and islanded mode disconnected from the main grid at the point of common coupling (PCC) in case of faults and be reconnected once the fault has disappeared [7-8]. In addition, a microgrid must have its own control to ensure the correct operation and coordination of the different DERs.

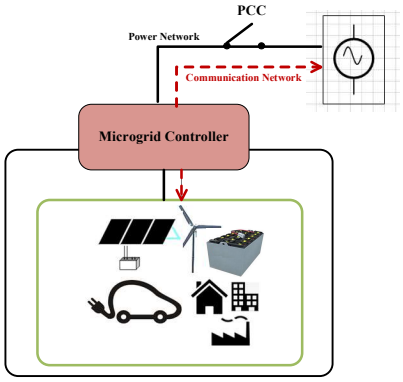

Fig. 1. Simplified scheme of a microgrid.

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The communication network plays a critical role in microgrids due to the increase number of renewable resources and microgeneration units (Distributed energy resources, DERs) that are being deployed in them [9-10]. Now, the communication infrastructure must have the ability to easily handle an increasing amount of data traffic or services requests and must to provide a real-time monitoring and control operation of all these nodes leading to move from a centralized communication infrastructure to a decentralized one [11].

The evolution towards the future smart microgrid requires the development of distributed communication architectures and protocols [12-13]**.** Recently a new paradigm of Peer-to-Peer (P2P) communications has become the focus of intense research in the field of control and communication structures in microgrids due to they allow robustness, efficiency, scalability and flexibility characteristics [14-15]. To add smart control which achieves efficient energy management of distributed energy resources, Peer-to-Peer (P2P) has been considered as promising technology that can provide interesting opportunities on control and optimization microgrid operation [16-17].

Peer-to-peer (P2P) overlay networks are distributed systems without any hierarchical organization or centralized control. These systems avoid a single point of failure and are scalable because the available resources grow with the number of nodes joining the network. Nodes are capable to cooperate to achieve a common goal and they have self-organization capabilities. In these networks the connectivity between nodes is carried out through a physical IP network while network topology is created in a virtual network, called overlay, which are built on top of the physical networks. Overlays allow increased flexibility, extensibility and adaptive reconfiguration. This implies that each node communicates with each other to create self-organizing overlay structures on top of the subjacent physical networks [16].

There are two classes of overlay networks: Unstructured and Structured. Traditionally Peer-to-Peer networks are mainly developed for file sharing and both structured and unstructured overlay P2P systems are designed for quick search and

efficient file storage mechanisms for a huge number of files [18].

On one side, unstructured P2P network has a random and unstructured mesh network topology. There is not an algorithm for organization. The information and data resources are distributed among peers. Flooding lookup technique is used to locate resources and data retrieval in unstructured P2P. Each peer that uses this technique propagates a request to directly connected peers through a successively deeper search in the system. The propagation remains until the message time to live (TTL) threshold (typically four) has been exceeded [19]. This flooding creates a large amount of signal traffic and makes use of a lot of network bandwidth and very high CPU/memory usage [20]. These characteristics do not result in a scalable and efficient system.

On the other hand, structured P2P networks have a dedicated network and a well-defined topology where peers are responsible to the information and data resource. In structured overlays, Distributed Hash Tables (DHT) is used to routing in order to locate resources in the network. In this strategy each peer has a local table (DHT-Distributed Hash Tables) which is used as a lookup algorithm to route the request data according to node tables. DHT tables allows peers find data addressed using flat identifiers (IDs) where IDs and IP addresses node are registered for each neighboring node. This kind of P2P system improves the network communication usage.

Fig.2 compares the performance of flooding and DHT lookup algorithms for distributed peer to peer architectures. The complexity of each of these lookup algorithms can be calculated through message counts. Message counts are considered as metric values for communication overhead [21] and can give evidence of network and bandwidth usage and end-to-end latencies. Computational behavior of these lookup algorithms is defined under O notation that especially describes the worst case scenario for n nodes in the network.

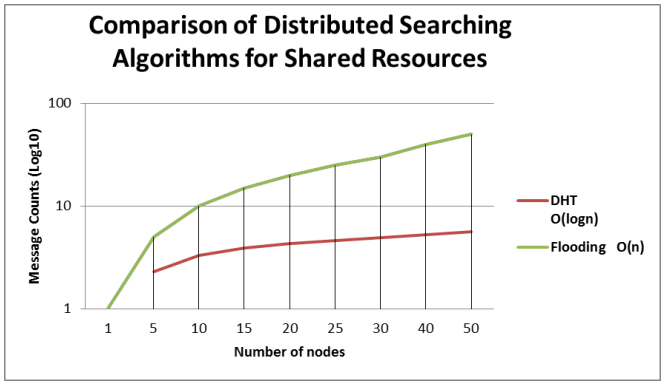

Fig. 2. Numerical analysis for comparison lookup P2P algorithms.

As shown in Fig. 2, DHT is the most efficient lookup technique, since the resources discovery can be satisfied in a bounded number of steps even in a large scale distributed systems.

The proposed algorithm is based on Chord protocol. For DHT lookup algorithms, Chord is the most popular structured routing protocol [22]. Chord DHT-overlay organizes peers on a virtual ring topology. In this protocol each node is responsible of a collection of keys in the space of keys. Each node in the ring upholds a routing table, called the finger table, which is used by the lookup algorithm. The lookup algorithm is started by one node in the ring in order to find a particular key in the space-keys or by an external request and follows these steps [22]:

1. Firstly checks if the node which started the search is in charge of that key. If this is true the search is over and the algorithm ends.
2. Otherwise the node will employ its finger table to localize the successor of the target node's key and request the search of the key to the target node.

As described, Chord specifies which node is responsible of each group of keys and it regulates communication between nodes. However, Chord does not specify any retrieval data mechanism [23], i.e. each node stores keys to locate information of the key which is responsible, although each node should stablish its own methods to find this information. In addition, traditional DHT-Chord does not consider locality [24]. Locality allows creating a group of peers for a particular task [25]. Peers with close interests create "shortcuts" and use them to locate content. The underlying physical network path could be significantly different from the path on the overlay network if locality in DHT-Chord is not considered. Therefore, the lookup latency in the overlay network could be quite higher and decrease the performance of the applications running over the DHT–Data Layer [26-27] (See Fig. 3). In the specific case of microgrids, these logical groups are often categorized by their nodes functionality (loads, generators, storage system, etc.)[28].

As a result, for achieve these capabilities and create an operational peer, several software layers need to be built [29-30] as shown in Fig.3.

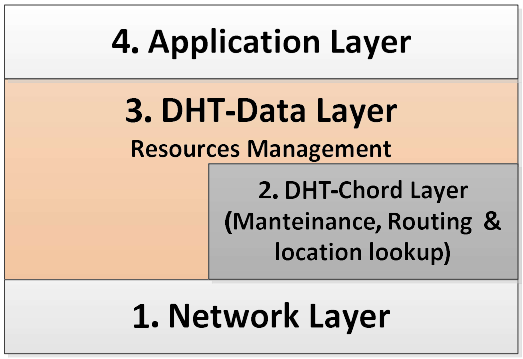

Fig.3. Main Functional Layers of a Peer-to-Peer Application

On the basis of Chord lookup algorithm, the target to achieve in this work is to embed DHT-Data layer functions (layer 3) into DHT-Chord Layer (layer 2) trying minimizing impact of the lookup Chord algorithm to the network performance. This is very important indeed for microgrids since peer-to-peer networks are principally developed for file and processor cycle sharing and network usage resource are less critical than microgrid operation where high efficiency in terms of quality network requirements (high bandwidth and low-latency) is required [31-33].

In this way, a new clustering algorithm based in Chord approach has been developed. DERs functionality has been embedded into finger table and routing management has been modified in order to:

1. Add locality capabilities for creating node clusters with close interests.
2. Provide location of information and data retrieval.
3. Reduce communications overhead.

An experimental setup has been build up to evaluate the performance of the proposed algorithm.

Fig.4 shows the comparison of proposed and Chord algorithm.

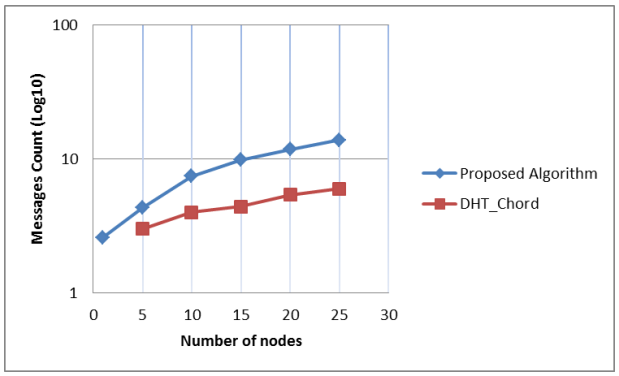

Fig. 4. Average Messages count comparison between proposed lookup and retrieval data algorithm and chord lookup algorithm with different network size.

It can be seen, the differences are not significant, as might be expected. Chord algorithm average messages are referred only to the lookup process while proposed algorithm the messages count are referred to total average messages sent into the network for lookup and retrieval processes, thus enabling the reduction of the overall data traffic on the network and end-to-end latencies.

In the case this work will be accepted, in the extended version of the paper, it will be provided a detailed description of the proposed algorithm, its mathematical framework and other experimental results that not appear.

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