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## ABSTRACT

The Wireless Smart Utility Networks (Wi-SUN) alliance promotes interoperable wireless standards-based solutions for Internet of Things (IoT) deployments, such as distributed automation (DA). For some applications, such as smart utility or smart city applications, it is desirable to provide optimized peer-to-peer (P2P) routing. However, for P2P traffic within a Destination Oriented Directed Acyclic Graph (DODAG), packets either have to be routed through a root in a non-storing mode or through a common ancestor in a storing mode. Techniques herein provide for locally reusing and distributing projected directed advertisement object (P-DAO) tracks. For example, when a node receives a P-DAO track from the root, the node advertises the P-DAO track to its neighbors so that they may reuse the track. Before a node sends a P-DAO request (PDR) to the root, the node first broadcasts a polling to its neighbors to look for an existing P-DAO track that can be reused.

## DETAILED DESCRIPTION

As noted, the Wireless Smart Utility Networks (Wi-SUN) alliance promotes interoperable wireless standards-based solutions for Internet of Things (IoT) deployments, such as distributed automation (DA). A DA network includes a border router (BR) as a root and multiple nodes that may be interconnected to form a multi-hop Low-power and Lossy Network (LLN). In some DA applications, peer-to-peer (P2P) communications are an important feature since DA applications typically involve Quality of Service (QoS) requirements in terms of latency and reliability.

For some applications, such as smart utility or smart city applications, it is desirable to provide optimized P2P routing. However, for P2P traffic within a Destination Oriented Directed Acyclic Graph (DODAG), packets either have to be routed through a root in a non-storing mode or through a common ancestor in a storing mode.

Such traffic is likely to traverse a longer routing path, which can impact latency, reliability, throughput, and packet delivery ratio. Furthermore, all P2P packets traversing the root or a common ancestor may cause network congestion. A better solution is obtained with route projection, also referred to as projected directed advertisement object (DAO) or P-DAO, as described in Internet Engineering Task Force (IETF) document 'draft-ietf-roll-dao-projection/'. Route projection involves a Path Computation Engine (PCE) that is collocated with the root. For simplicity, the root can represent a PCE for discussions herein.

During operation in current implementations, when a source node wants to send packets to a destination node, it sends a projected DAO Request (PDR) message to the root. The root then replies with a P-DAO message containing P2P routes (also referred to as a P2P track) to the source node. Thereafter, packets can be routed from the source to the destination through the P2P track. It should be noted that a P2P track is considered to include a set of P2P paths.

Consider an example topology as illustrated in Figure 1, below.

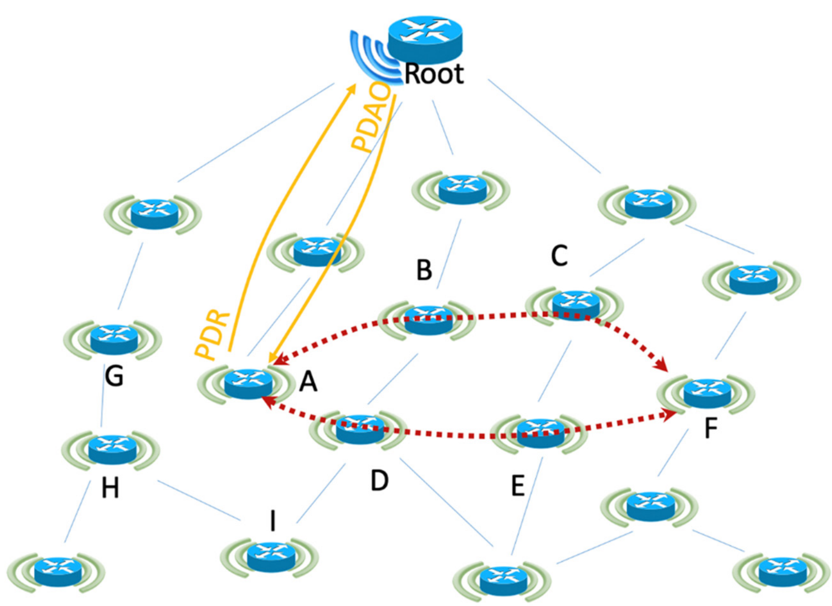


*Figure 1: Example Topology Involving P2P Communications*

For the example topology of Figure 1, consider an instance in which Node A wants to communicate with Node F. In current deployments, Node A would typically send a PDR to the root and the root would reply to Node A via a PDAO message including a P2P track: A->B->C->F and A->D->E->F.

Provided herein in this proposal are novel techniques that improve the current DAO projection method in the following two aspects:

- In a traditional PDAO, all the PDAO related traffic is sent to/from a single root, which may a bottleneck. Moreover, an excess of downward traffic may cause congestion since downward communications are expensive in LLNs.
- The root computes P2P paths based on learning a network topology from DAO messages (which may provide an enhancement of IETF Request For Comments (RFC) 6550). In some instances, the root might not be able to find optimal paths since it may not know all the local neighboring information.

In particular, techniques herein provide a novel mechanism for building P2P paths by locally reusing existing P2P paths. Such techniques may provide several benefits, such as 1) accelerating P2P path building by reusing existing P2P paths; 2) easing the burden of a single root and reducing traffic on bottleneck links; and 3) providing for the ability to find optimal P2P routes by using local information that the root may not know.

In the DAO projection RFC (https://datatracker.ietf.org/doc/draft-ietf-roll-dao-projection/), when a source node wants to setup a P2P track to a destination node, the source node needs to send a PDR request to the root. The root then replies the source node with P-DAO messages containing the P2P track. Consider an example topology, as shown below in Figure 2.

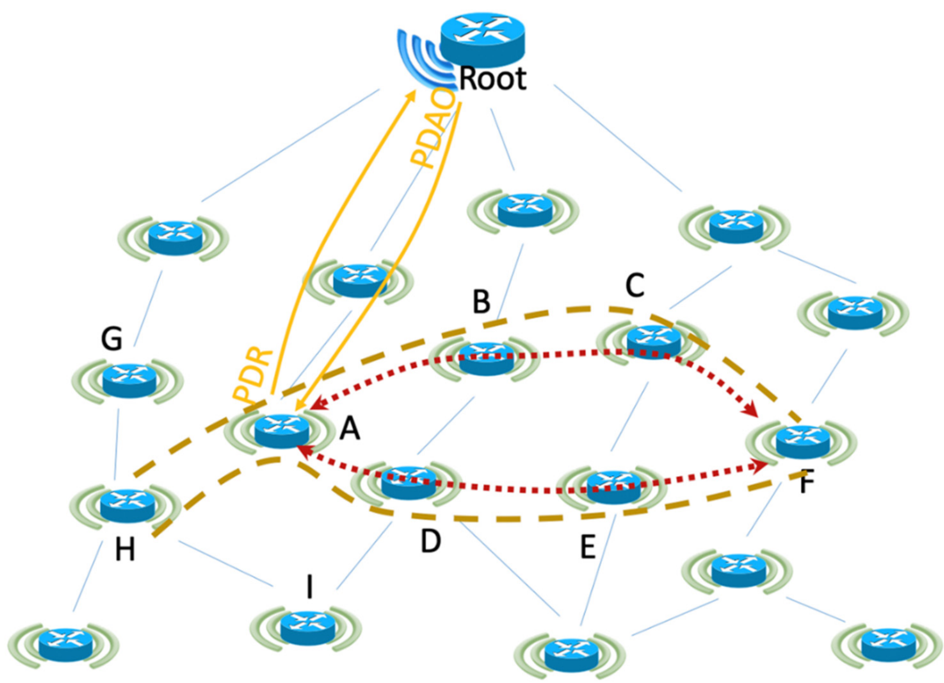


*Figure 2: Example Topology Facilitating Accelerated P2P Communications*

In the example topology of Figure 2, consider that Node A sends a PDR to the root and the root sends a P-DAO message to Node A with two P2P paths: A->B->C->F and A->D->E->F.

In accordance with techniques of this proposal, the PDR request to the root can include a flag indicating that the computed P-DAO track is to be re-distributed by the source. Upon obtaining the P2P track computed by the root, Node A can advertise the P2P track to its neighbor nodes using DODAG Information Object (DIO) messages. The neighbor nodes may thereafter reuse the information to more efficiently setup their own P2P paths, as needed.

Two methods may be utilized to advertise a P2P track. For a first method, a source node can advertise the source and destination address of a P2P track to its neighbors and indicates that it knows a P2P track. If a neighbor node desires to receive the advertisement and also needs to setup a P2P track to the same destination, it can send a request to the source node to obtain the P2P track. For a second method, a source node can advertise the whole P2P track to its neighbors. A neighbor node that receives the advertisement can then build its own P2P track, as needed.

In one example, regarding the topology of Figure 2, after Node A obtains a P2P track (A->B->C->F and A->D->E->F) from the root, Node A also advertises the P2P track (A->B->C->F and A->D->E->F) to its neighbors. For example, Node H may receive the advertisement and may build its own P2P track to Node F, when needed as (H->A->B->C->F and H->A->D->E->F).

There may be instances in which a node may miss a P2P track advertisement message from its neighbors. Thus, in some instances before a node sends a PDR message to the root to request a P2P track, the node can send a P2P track query message to its neighbors to determine whether there is any P2P track the node can reuse. A neighbor, knowing the corresponding information, can then reply to the node with the P2P track.

In one example regarding the topology of Figure 2, consider that Node H sends a P2P track polling message to its neighbors to ask for a P2P track to destination Node F. In this example, when Node A receives the polling message, it can reply with the P2P track (A->B->C->F and A->D->E->F) to Node H. Thereafter, Node H can builds its P2P track to node F, such as (H->A->B->C->F and H->A->D->E->F).

In some instances, the root might not know that Node H is a neighbor of Node A. Thus, the root might not compute an optimal P2P track from Node H to Node F. In this case, Node H could report its useful local neighbors to the root to enable the root to make better decisions in the future. Thus, in some instances, techniques herein may provide that after a node builds a P2P track based on localized information, it can send a DAO message to the root containing a list of useful neighbors, such that the root can use the neighbor information to compute a more optimal P2P track.

In summary, techniques of this proposal provide for locally reusing and distributing P-DAO tracks. When a node receives a P-DAO track from a root, the node advertises the P-DAO track to its neighbors so that they may reuse the track. Further, before a node sends a PDR to the root, the node can broadcast a polling to its neighbors to look for an existing P-DAO track that can be reused. Advantageously, no local trees are generated for techniques of this proposal. Rather, the techniques extend the P-DAO mechanism and reuse P2P paths to accelerate P2P path generation. Further, the DIOs for advertising existing P2P paths are only sent to neighbors of a node. The DIOs do not spread. Thus, techniques of this proposal may limit overhead that is typically caused by DIO spreading.