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## A NOVEL INTER-PERSONAL AREA NETWORK COMMUNICATION MECHANISM FOR LARGE-SCALE LOW-POWER AND LOSSY NETWORKS

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## A NOVEL INTER-PERSONAL AREA NETWORK COMMUNICATION MECHANISM FOR LARGE-SCALE LOW-POWER AND LOSSY NETWORKS

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### ABSTRACT

For large-scale Low-Power and Lossy Networks (LLNs), communications between nodes in different Personal Area Networks (PANs) (i.e., inter-PAN communications) typically have to traverse long routing paths, even for cases in which two nodes may be located physically close to each other. Techniques herein provide a novel mechanism to improve inter-PAN communications by utilizing the nodes that are located at the boundary of PANs.

### DETAILED DESCRIPTION

Many wireless mesh network solutions, such as Wireless Smart Utility Network (Wi-SUN) solutions, are being developed for smart utility and smart city industries. For current mesh network implementations, a deployment typically consists of a large number of Personal Area Networks (PANs) in which each PAN is composed by a border router (BR) as the root and hundreds/thousands of nodes, forming a large-scale multi-hop Low-power and Lossy Network (LLN).

In such LLNs, the communications between nodes in different PANs (inter-PAN communications) typically have to traverse a long routing path, even if two nodes are physically close to each other. Consider an example deployment involving multiple PANs, as shown below in Figure 1. As shown in Figure 1, communications between Node A and Node D have to traverse the long red path.

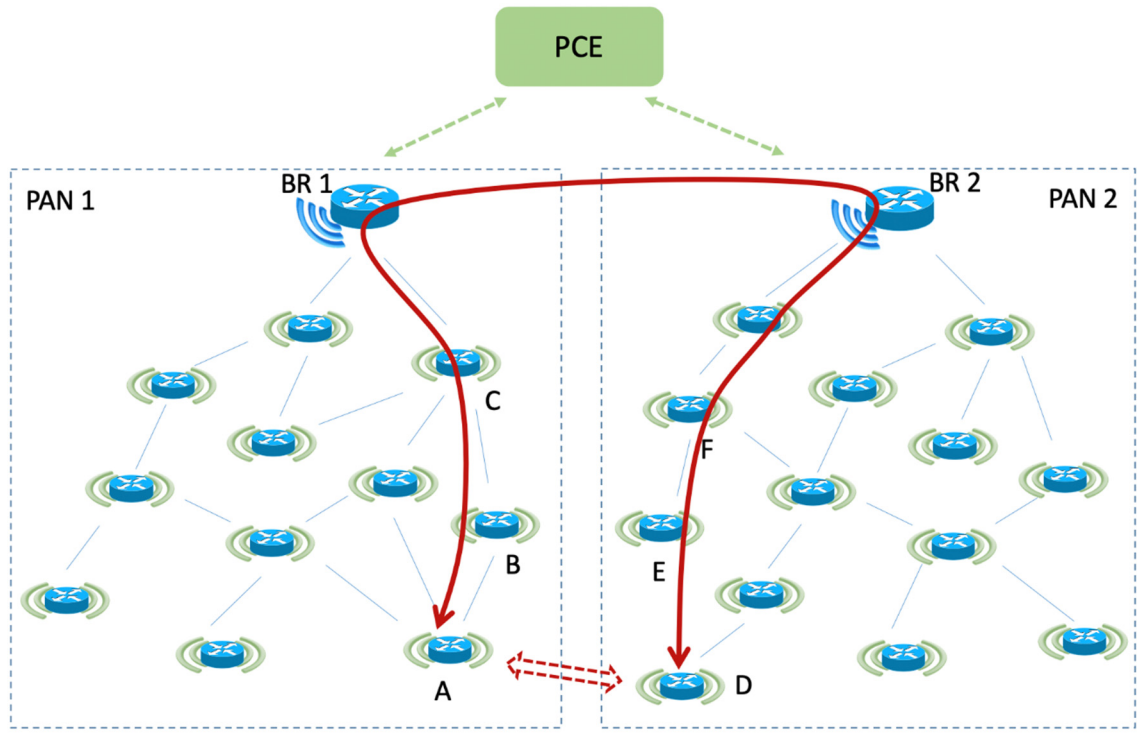


Figure 1: Illustrative Inter-PAN Communication Example

This proposal provides novel techniques to improve inter-PAN communications by utilizing nodes at the boundary of PANs in order to build a shorter route for inter-PAN communications.

Various example steps for performing the techniques of this proposal may include, identifying border nodes, forming a local Routing Protocol for LLNs (RPL) Destination-Oriented Directed Acyclic Graph (DODAG), and reducing the probability of PAN migration.

**1. Identifying Border Nodes**

To begin, consider various example details that may be performed in order to identify border nodes. During operation, if a node receives a DODAG Information Object (DIO) from two PANs, the node can set its state to 'pending'. Such a 'pending' state may be utilized to indicate that the node is a potential border node.

Consider, as illustrated in Figure 2 below, for example, that Node B receives a DIO from Node C belonging to PAN 1 and Node F belonging to PAN 2. In this example, Node B sets its state to 'pending'.

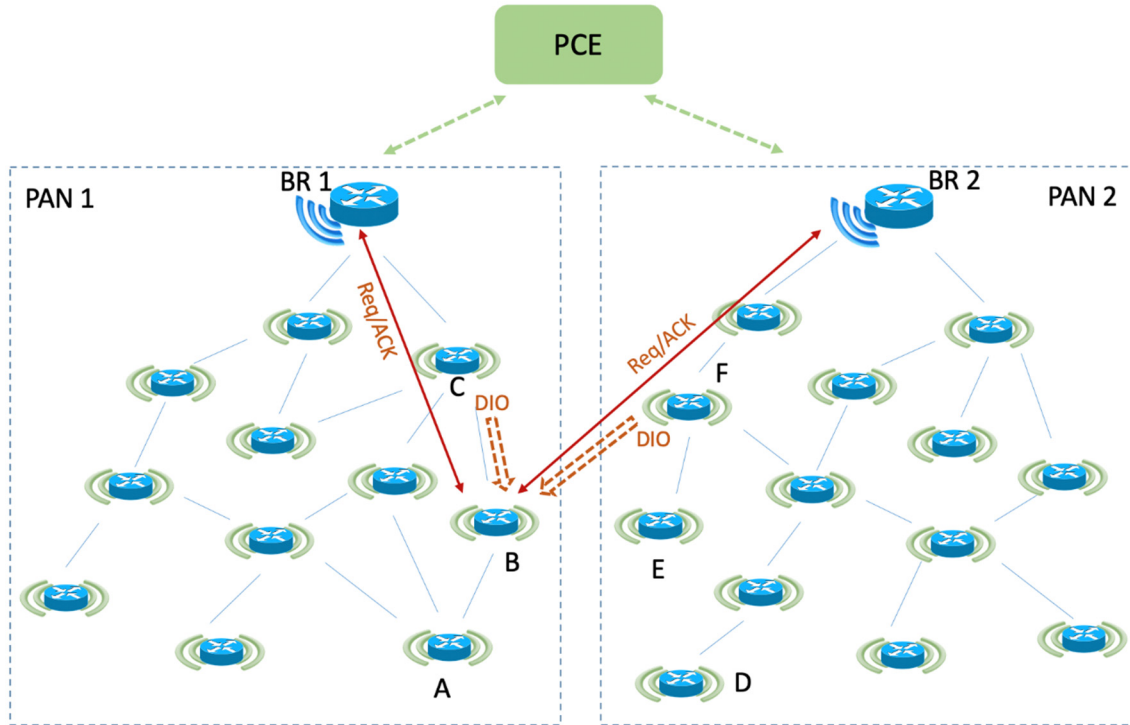


Figure 2: Example Details for Identifying a Potential Border Node

A node in a 'pending' state will send requests to the Border Router (BR) for each PAN through its proxy nodes. If the node receives an acknowledgment (ACK) from both BRs, then it changes its state from 'pending' to 'confirmed'. Thereafter, the 'confirmed' border node can send a Destination Advertisement Object (DAO) to the BR to indicate to the BR that it is a border node.

Continuing with the example for Figure 2, Node B sends respective requests to BR1 and BR2 through proxy Node C and Node F, respectively, and waits for a corresponding ACK from each BR. After Node B receives both ACKs, it sets its state to 'confirmed' and sends DAOs to BR1 and BR2, so that both BRs know that Node B is a border node.

All other nodes located at the boundary can set their states in a similar manner. Thus, the BR for each PAN can identify all the nodes in the PAN are border nodes.

## 2. Forming a Local RPL DODAG

Following the identification of border nodes for the two PANs, the border nodes will obtain security keys for the two PANs so that they can decrypt messages from both PANs. The border nodes will form a local RPL DODAG and the BR for a given PAN will advertise the list of border nodes to the PAN through DIO messages.

Continuing from the example of Figure 2, either BR1 or BR2 will act as the DODAG root. For example, as illustrated in Figure 3, below, the red Nodes (A, B, C, D, E, and F) will form a local RPL DODAG with BR1 as the root. Further as illustrated in Figure 3, BR1 will advertise to PAN 1 that Nodes A, B, C are border nodes and BR2 will advertise to PAN 2 that Nodes D, E, and F are border nodes.

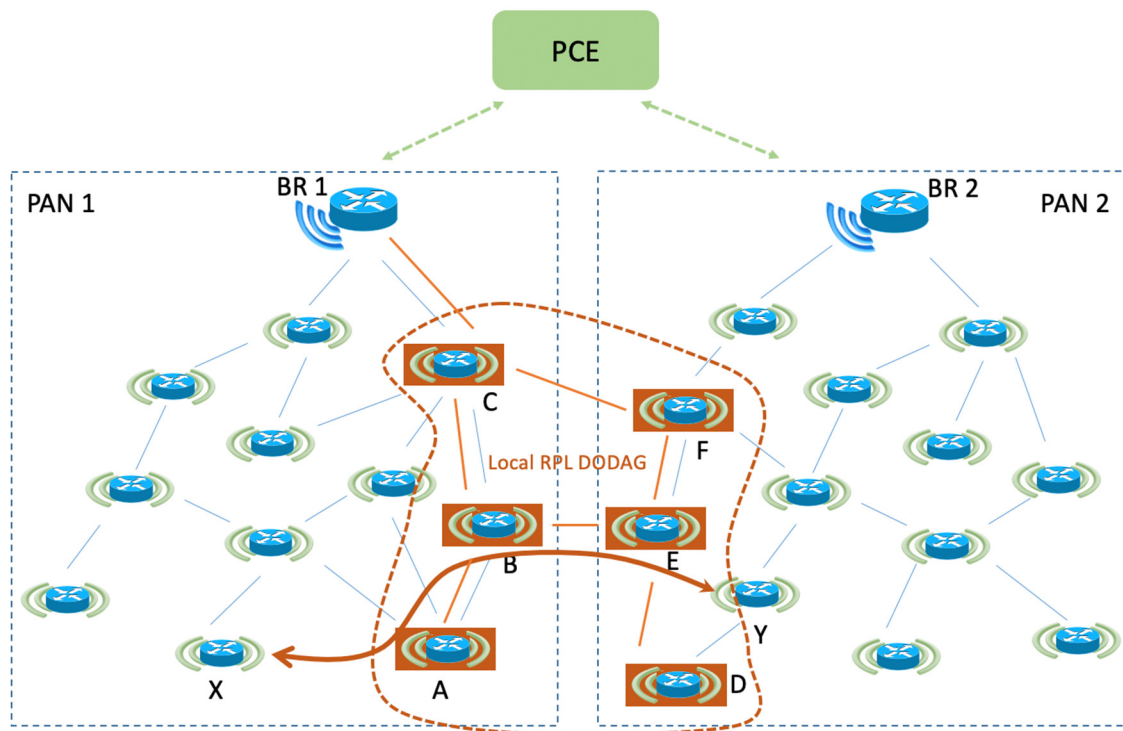


Figure 3: Example Details for Forming a Local RPL DODAG

Following formation of a local RPL DODAG the BR advertisements for each PAN, when a given node desires to communicate with a node in another PAN, the node first sends a Projected DAO Request (PDR) message to the BR within the first node's PAN (e.g., as described in <https://tools.ietf.org/pdf/draft-ietf-roll-dao-projection-14.pdf>). The BR then forwards the request to a Path Computation Engine (PCE) and the PCE computes a peer-

to-peer (P2P) path and pushes that path to the requesting node. Since the border nodes are in the same local RPL DODAG, such an inter-PAN communication can travel through a much shorter P2P path.

Using the proposed mechanism, as shown in Figure 3 for example, the P2P route (X->A->B->E->Y) between Node X and Node Y is much shorter than traditional method which would involve Node X communicating upward to BR1, from BR1 to BR2, and then downward from BR2 to Node Y.

### **3. Reducing the Probability of PAN Migration**

For the border route, techniques of this proposal set a higher threshold for migration than other nodes. Thus, the border nodes will not frequently migrate back-and-forth between PANs and each PAN will be more stable.

In summary, this proposal provides techniques to build shorter routes for inter-PAN communications. During operation, potential border nodes can send requests to their respective BRs in order to confirm their 'border' states. Thereafter, the border nodes can form a local RPL DODAG to aid with forwarding inter-PAN traffic and the BR for each PAN can advertise a list of border nodes to other nodes within its PAN so that the other nodes can utilize the border nodes for inter-PAN communications.