Social-aware Peer Discovery for Small Cell based Device-to-Device Communications

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***Abstract*—In this paper, we propose a peer discovery method for Device-to-Device (D2D) communications using Multi-Attribute Decision Modeling (MADM) technique. The method exploits both physical and social characteristics of User Equipment (UE) to find the most suitable partner for D2D communication. A small-cell based scenario is considered with the aim to pair the UEs with similar social and physical characteristics. Various social and physical attributes are used to rank the UEs and select the best one as a D2D partner. Simulation and analysis results are provided for various performance parameters.**

Keywords-Device-to-Device; User Equipment; Peer Discovery; TOPSIS; Small Cell etc.

I. INTRODUCTION

Small-Cell Network (SCN) and Device-to-Device (D2D) communications are believed to be the emerging solutions for the heavily loaded cellular networks [1]. Since both paradigms aim to provide low cost, low power and short-range communication and reduce the burden on Macro-Cell Base-Station (MCBS), they can be integrated to exploit both the licensed and unlicensed spectrum bands for direct communication between Cellular User Equipment (CUEs).

In order to establish a D2D link between two CUEs, the source UE needs to discover the target UE with the desired service. The peer discovery may be performed with or without the assistance of Base-Station (BS) or eNodeB (Evolved Node B). The former method can improve the peer discovery process at the cost of higher signaling overhead. Similarly, the latter approach can achieve scalability and out-of-coverage discovery but lacks synchronization and collision avoidance [2].

In this work, we propose a method based on Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) [3] for social-aware D2D peer discovery in SCN environment. It combines both the social and physical attributes of a UE to determine a suitable partner for D2D communication. A decision matrix is constructed where the UEs connected to the Small-Cell Base Station (SCBS) are considered as alternatives and various social and physical attributes as constraints. The decision matrix is then normalized and used to calculate the positive and negative ideal solutions. Then, based on the distance from the two ideal solutions, the candidate UEs are ranked and the best one is selected for D2D communication. The SCN based scenario can overcome the issues in traditional macro-cell based D2D communication. Also, the method is easy to implement and power-efficient as the peer discovery process is performed by the SCBS rather than the UE itself.

The next section presents the problem definition and formulation. The third section discusses the simulation model and results and the final section summarizes the discussion with conclusion and future direction.

II. PROBLEM DEFINITION AND FORMULATION

D2D peer discovery is based on the physical and social relationship between human users. Users who are friends on social networks with same age group and profession are more likely to have similar choices. Moreover, for D2D communication the users also need to be located closely. Therefore, we consider both social and physical attributes to maximize the chances of willingness for D2D communication. For this purpose, we use TOPSIS method which ranks the available alternatives, i.e., UEs and select the best option based on the given attributes. The basic steps of the method are as follows.

Step 1: We construct a decision matrix D_m in which the rows consist of UEs as alternatives while the columns are based on various social and physical attributes of the corresponding UE as given in (1).

$$D_m = \begin{array}{c} \\ UE_1 \\ \vdots \\ \vdots \\ \vdots \\ UE_m \end{array} \begin{array}{c} \begin{array}{cccccc} At_1 & At_2 & At_3 & \dots & At_{p-1} & At_p \end{array} \\ \begin{bmatrix} X_{11} & X_{12} & X_{13} & \cdots & X_{1p-1} & X_{1p} \\ X_{21} & X_{22} & X_{23} & \cdots & X_{2p-1} & X_{2p} \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ X_{m1} & X_{m2} & X_{m3} & \cdots & X_{mp-1} & X_{mp} \end{bmatrix} \end{array} \quad (1)$$

where $X_{i,j}$ is the value of attribute At_j for UE_i.

Step 2: The values for each attribute have different scales. Moreover, we separate the attributes as desired and undesired attributes based on their impact on overall performance. So, we normalize the decision matrix to make it in uniform scale. The desired attributes are normalize1d as:

$$X_{i,j}^{nor} = \frac{X_{i,j}}{\sum_{i=1}^{m} X_{i,j}} \quad \text{where i} = 1,.\text{m and j } 1,\ldots\text{p} \quad (2)$$

while the undesired attributes are normalized as:

$$X_{i,j}^{nor} = 1 - \frac{X_{i,j}}{\sum_{i=1}^{m} X_{i,j}} \quad where\ i = 1,.m\ and\ j = 1,.p \quad (3)$$

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Step 3: Then based on impact on the performance we assign weights W to each attribute as:

$$X_{w(i,j)} = W_i * X_{nor} \quad where \ \sum_{i=1}^{m} W_i = 1 \qquad (4)$$

Step 4: Next, we find we find the Ideal positive (I^+) for each attribute and the ideal negative solution (I^-) as:

$$I^+ = \{Max\,(X_{W(1,j)}, X_{W(2,j)}, \dots \dots X_{W(m,j)})\} \ (5)$$

$$I^- = \{Min\,(X_{W(1,j)}, X_{W(2,j)}, \dots \dots X_{W(m,j)})\} \quad (6)$$

Step 5: Then using eq. (5) and (6), we calculate the distance of each solution from (I^+) and (I^-) as:

$$DI_i^+ = \sqrt{\sum_{j=1}^{p} (X_{w(i,j)} - I_j^+)^2} \qquad (7)$$

$$DI_i^- = \sqrt{\sum_{j=1}^{p} (X_{w(i,j)} - I_j^-)^2} \qquad (8)$$

Step 6: We then use DI_i^+ and DI_i^- from eq. (8) and (9) to calculate the coefficient of closeness to the ideal solution as:

$$CC_i = \frac{DI_i^-}{DI_i^- + DI_i^+} \quad where \ i = 1,,m \ while \ 0 \le CC_i \le 1 \quad (9)$$

Step 7: The final step is to rank the UEs in descending order based on the value of CC_i. The UE with highest value of CC_i is the best choice for D2D communication.

III. Simulation And Results

We performed simulations of the proposed scheme in MATLAB considering a small-cell environment with 10 UEs distributed uniformly. Social attributes like frequency of contact, contact duration, social media interaction and similarity of interest are considered as in [4]. Similarly, the physical attributes taken into account include the number of available services, distance from the source UE and the available interfaces. The SCBS provides assistance in D2D peer discovery and is assumed to have the mentioned information about the available UEs.

Initially, each attribute of a UE is assigned random values between 0 and 6. For simplicity, uniform weights are assigned to the attributes after normalization. Three simulation scenarios are considered separately based only on physical, social and both the physical and social attributes.

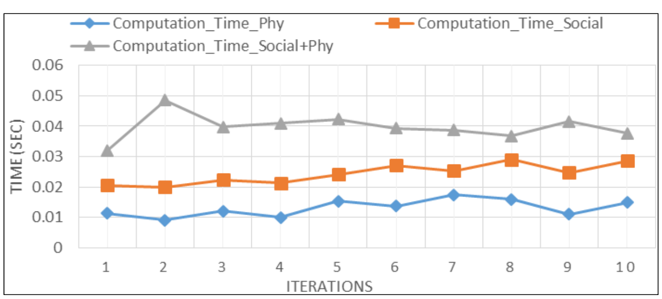

Figure 1. D2D peer Discovery Time vs. Iterations

The simulations are run for ten times and the results are plotted in terms of D2D peer discovery time and Peer discovery success ratio as shown in Figure 1 and Figure 2.

The results in Figure 1 show the D2D peer discovery time for scenario considering physical, social and the combination of physical and social attributes. The average time of discovering the best D2D peer is 39 ms.

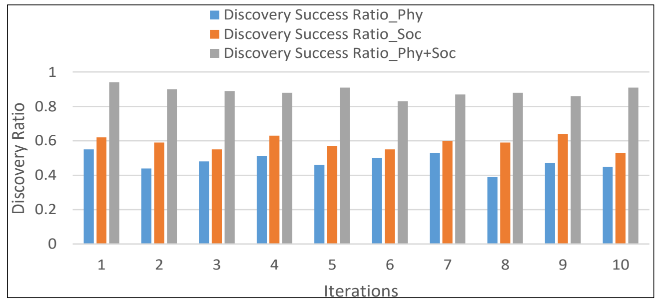

Figure 2. D2D Peer Discovery Success Ratio vs. Iterations

Similarly, we plot the results of D2D peer discovery success ratio based on comparison with the analytical results as shown in Figure 2. The average success ratio in the scenario considering both social and physical attributes is 88%. The proposed method is fast as it takes seven easy steps to find the best D2D peer. Similarly, it efficiently combines attributes of different impact in a simple manner.

IV. Conclusion And Future Direction

In this paper, we proposed a D2D peer discovery method based on multi-attribute decision modeling. The method is simple to implement, fast and improves the peer discovery process significantly. Simulation results demonstrate the efficiency of the method in terms of discovery time and success ratio. In the future, we aim to improve the work by considering more realistic scenarios and determine the impact of each attribute.

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