# Opportunistic Routing based on Two-tier Probability Model with Differential Privacy

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***Abstract*—ww**

***Index Terms*—Opportunistic Network, Differential Privacy, Gaussian Mixture Model**

## I. INTRODUCTION

Opportunistic routing provided the message forwarding scheme in various scenarios, including the wild-fields

The main contributions are as follows.

- we designed the two-tier probability model to profile the probability density of the future contact events in the message lifetime.
- we employed the inter-day probability based on the poisson process the intra-day probability pattern based on gaussian mixture model to measure the probability of sequential events. Multiple potential routes of message forwarding are utilized to support the routing decision.
- we exploit the local differential privacy to obscure the pattern of contact events.
- we evaluate the proposed scheme with the benchmarks, such as S&W, Epidemic, Prophet, in terms of the routing performance under various settings with the bike sharing trace.

## II. RELATED WORK

In this section, we first review the various selfish behaviors in OppNets. Then two existing categories of blackhole mitigating methods and the applications of machine learning in OppNets are discussed.

[1] introduce the pattern aware privacy preserving method.

## III. TWO-TIER PROBABILITY MODEL

We assume a set of nodes $\mathcal{N}$ in the network. In this paper, we mainly consider the message forwarding occurs by the bike trip among the bike stations. Thus the bike trip from node (station) $i$ to node (station) $j$ can provide the message forwarding opportunity from $i$ to $j$, but can not serve the message forwarding from $j$ to $i$. The bike trip can also be treated as the directional contact, which is denoted by $i \to j$.

### A. Inter-day probability

we assume that the contact events among the nodes are daily periodic and follow the Poisson process. Fig. 1** shows that the number of contacts in the range of year. We can find the contacts are regular among the successive days and vary slowly in the range of year. Let $\bar{C}_{ij}$ denote the expected number of contacts from $i$ to $j$ in one day. The probability that $i \to j$ occurs in a future day (after $k$th day) can be calculated as

$$p_{ij}^k = 1 - Prob\{\bar{C}_{ij} = 0\} = 1 - exp(-C_{ij}^k), \tag{1}$$

where the number of contact records in each day, e.g., $C_{ij}^k$ in $k$th day, will be collected in the end of each day.

Since the inter-day pattern may vary caused by temperature, holiday/workday, weather and air pollution, in the range of year, the inter-day probability of the contact occurrence, e.g., $P_{ij}^{k+1}$ in $k+1$th day, should be updated according to the contact records in each day. In this paper, we use the EWEA method (Exponentially Weighted Moving Average) to model the probability that at least a contact $i \to j$ can occurs in $k+1$th day, which is

$$P_{ij}^{k+1} = \begin{cases} p_{ij}^k, & \text{if } k = 0 \\ \alpha P_{ij}^k + (1-\alpha) p_{ij}^k, & \text{if } k \leq 1 \end{cases} \tag{2}$$

Here the weight coefficient $\alpha \in (0, 1)$.

Additionally, the probability patterns are different between the holidays and the workdays. If $k$th day is the holiday, including weekends, May 1st (Labour Day), Mid-autumn Festival, $C_{ij}^k$ should be utilized to calculate $Pw_{ij}^{k+1}$; otherwise $Ph_{ij}^{k+1}$. With this method, we can calculate the probability that the contact can occur at the beginning of each day.

### B. Intra-day probability

As Fig.2** shows, we find that the probability is not uniform in the range of day. The double-peak phenomenon in the contacts from the residence to the metro station is apparent. But

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