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Enhanced Incentive Schemes for Volunteers to Distribute Surplus Food in Smart Cities

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Abstract

Food wastage is a major problem in today's world and the distribution of food surplus is undoubtedly one of the leading solutions to the problem. Surplus distribution is widely practised across the globe and there are several communities for the same as well. However, the success of these movements are determined by the active participation of volunteers. In addition, volunteer availability is an issue that is dependent on several different factors. An incentive module for the volunteers can normalize the availability of the volunteers. Such incentive modules are prone to identity duplication attacks and the implemented solutions do not really encourage volunteer hierarchical structures. In this paper, an incentive module that resists identity duplication and promotes the hierarchical structure between volunteers is presented. In addition, an improved matching module to match the food donors to the receivers utilizing the available volunteers optimally is also proposed. For the simulation, we have used real data taken from a real life smart city context, namely, we have used the OPEN DATA BARCELONA at `https://opendata-ajuntament.barcelona.cat/data/en/dataset/est-cadastre-carrecs-us` and cast it to our simulation settings using Python libraries.

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Keywords:
Food surplus, Surplus food distribution, Food recovery, Food wastage, Volunteer incentive, Volunteer participation, Sybil attack

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Graphical Abstract

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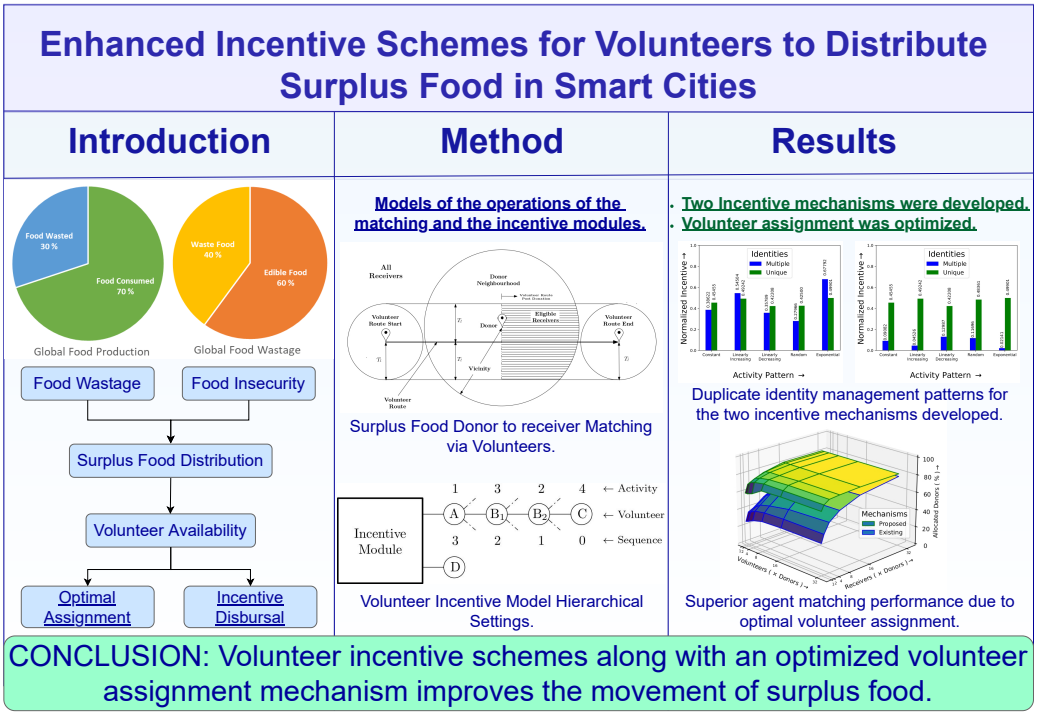

Highlights

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- The food donor to receiver matching mechanism is proposed to include a larger pool of volunteers for each surplus donor from where an optimal volunteer is assigned. This increases volunteer utilization leading to a higher surplus mobility.
- An incentive mechanism is proposed for the volunteers to attract better participation in moving the surplus food. This stabilises the availability of volunteers over the different factors, resulting in the robust performance of the proposed mechanism.
- Two methods for the disbursal of volunteer incentives are suggested that are suitable for different kinds of volunteer incentive setup requirements.
- One of the methods favours the volunteers in terms of a higher incentive amount. However, the volunteers may gain more incentive by using duplicate identities.
- The other method favours the system in terms of being resistant to identity duplication at the cost of lower incentives disbursed to the volunteers.
- The modified matching mechanism along with the two proposed incentive disbursal methods produce superior results when compared to that of the existing method.

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Abstract

Food wastage is a major problem in today's world and the distribution of food surplus is undoubtedly one of the leading solutions to the problem. Surplus distribution is widely practised across the globe and there are several communities for the same as well. However, the success of these movements are determined by the active participation of volunteers. In addition, volunteer availability is an issue that is dependent on several different factors. An incentive module for the volunteers can normalize the availability of the volunteers. Such incentive modules are prone to identity duplication attacks and the implemented solutions do not really encourage volunteer hierarchical structures. In this paper, an incentive module that resists identity duplication and promotes the hierarchical structure between volunteers is presented. In addition, an improved matching module to match the food donors to the receivers utilizing the available volunteers optimally is also proposed. For the simulation, we have used real data taken from a real life smart city context, namely, we have used the OPEN DATA BARCELONA at `https://opendata-ajuntament.barcelona.cat/data/en/dataset/est-cadastre-carrecs-us` and cast it to our simulation settings using Python libraries.

Keywords:
Food wastage, Food recovery, Surplus food distribution, Volunteer incentive, Volunteer participation, Sybil attack

1. Introduction

The global issue of food wastage has been dealt with by the help of surplus distribution. This approach has been accepted as the most viable solution to the challenge. The usage of technological platforms available in existing and upcoming smart cities have rendered this approach highly scalable and naturally sustainable in the long run. However, the success of

such movements relies heavily on the participation of volunteers. That, in turn, is dependent on various factors including, but not limited to, the season, the time of the day, the weather conditions, ongoing festivities, etc. The Food Donor to Receiver Matching with Chronological Acceptance (FDRM-CA) was proposed in our work [1]. An incentive module was developed to encourage volunteer participation as well [2].

However, it was noted that the presented incentive scheme was susceptible to identity duplication attacks and the solution implemented therein did not particularly favour hierarchical volunteer engagement in distribution activities. Here, in this work, we present an incentive module that resists such identity duplication attacks and encourages volunteer hierarchical work structure. Furthermore, it also rewards volunteers for promoting the scheme to other volunteers. We also improve upon the matching module so that it can produce better results under tighter volunteer availability conditions. For the simulation, we have used real data taken from a real life smart city context, namely, we have used the OPEN DATA BARCELONA at `https://opendata-ajuntament.barcelona.cat/data/en/dataset/est-cadastre-carrecs-us` and cast it to our simulation settings using Python libraries.

This paper is organized as follows. Section 2 presents the related work in this field. The system model and the proposed mechanism have been discussed in Section 3. The mechanism has been analyzed in Section 4 and its simulation results presented in Section 5. A discussion about the outcomes of the simulations has been put forward in Section 6 followed by conclusion and future work in Section 7.

2. Related Work

We have already provided a food donor to receiver matching algorithm [1] and a volunteer incentive generation algorithm [2]. This paper aims at improving the incentive mechanism so as to make it better immune to identity duplication attacks (sybil attacks). It also modifies the matching mechanism so that it produces optimal matches under reduced volunteer availability conditions.

Wastage of food is the top concern for people across the globe as it leads to several other social and economical issues [3]. Amounting close to one third of the food production, most of this billions of tonnes of wasted food is still in perfectly edible condition when being discarded [4, 5]. Solutions

to this issue are several. However, the distribution of surplus food works for this issue as well as the issue of food supply to those in need.

Far from new, the distribution of surplus food is already observable in the society with credible support from the Information and Communications Technology (ICT) platforms [6]. Further useful contributions are noted from the usage of the Internet of Things (IoT) in the terms of traceability and accountability [7].

The steep growth of ICT based platforms is well documented and the impact of food donation on the society is also captured [8]. The reverse of the same, that is, the impact of society and culture on the donation of food, is also explored [9]. Food distribution has also been pointed out as a solution to the rampant challenge of global climate change [10]. Volunteer participation and ICT platform usage are the top reasons for the success of such low running-cost ventures. A centralised food collection and distribution body goes a long way in making the food distribution activity more sustainable [11]. The economically better approach of food distributed in bags has also been studied. The use of IoT in parallel with ICT in communicating the run-time food wastage to the users of a canteen is another idea explored [12]. Current market practices and their impact along with better suggestions is given as well [13]. *OLIO* (`https://olioex.com/`), a food distribution service delivered over handheld device apps, has shared their operating metadata for a study confirming that the relationships developed in the food distribution process contribute in the development of new policies that further promote the use of ICT platforms in this domain [14]. The reverse has also been proven to be true. That is to say, existing policies play a major role in encouraging or discouraging food distribution as well [15, 16].

The use of ICT based platforms positively speed-up the movement of surplus food across a broader geographical area [17]. Local food redistribution has been found to produce opportunities as well as pose challenges [18]. The high dependency of food value evaluation on the food practices of the region has also been pointed out. Research [19] on *Food for Us* (`http://foodforus.co.za/`), a South African app that bridge small-scale producers with markets shows that the involvement of technical platforms help mobilize unsold produce. The thin line of difference between food and waste is highlighted and the factors that contribute to the decision making process have been pointed out [20]. The dual challenges of food wastage and food unavailability have been shown to be addressed by surplus distribution [21]. Pointing out at the food wastage laws prevailing in Italy, it has been

argued that such laws encourage the adaptive/discounted pricing of expiring food items. Food sharing among peers has been shown to attract a diverse set of actors [22]. Food distribution also creates networks of sharing individuals where the use of ICT based platforms play a major role [23]. Food distribution in cities is a major field for research and development [24].

Adaptive pricing for items having wildly fluctuating demand has been proven as a great plan for mitigating wastage [25]. The contribution of ICTs in minimising costs and inefficiencies, and maximising productivity and coordination leading to a better food movement experience is recognised [26]. The most benefit of ICT based coordination is pointed out to be received by those perishable food items that have a very short shelf life [27]. This study also mentions that along with the capability of ICT platforms to cover a geographically wider area comes the moral and social challenges of percolating to diverse localities. This is exactly why surplus distribution gets the nickname "messy" highlighting the fact that the heterogeneity of participants and practices get involved with surplus distributions using ICT based platforms [28]. Multiple food production stages observe the benefits of using ICT based platforms, although, the retail one tops the charts [29]. They have also discussed the urban notions for differentiating edible food from waste food and have suggested a few of their own. The rules of the land are as important as all other factors and play a major role in shaping the behaviour of the participants in the act of surplus distribution [30]. The same has been shown to shift us towards a more sustainable economy and get a diverse demography together for the act boosting the economy further [31]. The diverse motives, interactions and the operational effects of surplus distribution were brought to light along with the different options for the participants [32]. Individual food initiatives across several countries were studied with respect to sustainability and were documented as a database [33].

There is confidence on the reinforcing effects of ICT on surplus distribution and pattern analysis and prediction along with database creation of such activities are already noted [34]. Surplus distribution along with infrastructure changes in the food production system is believed to be a practical solution towards food waste reduction [35]. This approach is expected to counter the increasing demands of food as the population of the world grows. In addition, there is no doubt that the current practices in handling food are nowhere near sustainable in terms of the society, the economy or the environment. In the United States alone, at least 12% people suffer with food insecurity whereas a third of the produce is dumped under the soil [36].

Surplus distribution can counter this effect, albeit with more profound effect in certain areas than others. Not only that, surplus distribution has been shown to have positive impacts on the environment, economy and society [37]. The irony of food wastage and food insecurity coexisting in close proximity in the US has been highlighted [38]. The opacity of school policies and strategies in handling food wastage has been observed and several factors contributing to the choice of some policies are noted. Traceability of food is an often ignored domain that aids in guaranteed food safety and quality [39]. Nonprofit organizations (NPO) improve the value of the surplus by adding fresh produce to it while acting as agents in the movement of the same [40]. However, they require added support in terms of infrastructure and regulations to implement this. Surplus distribution is far more preferable than landfills. Although composting comes real close in terms of benefits, both options used together promises the maximum utility for a sustainable future [41]. Shelf-life of perishable items forcing its price to be dynamic is a great policy for the reduction of food waste and also for generating good revenue [42, 43]. This has been observed with items having different expiry dates and prices driving buyer behaviour [44].

Food Tank (`https://foodtank.com/`) points out to the fact that several food sharing communities operate at a global scale. ICT, in simple forms, is used my most of them so as to connect the donors and the receivers, albeit passively over social media [45]. ICT, used in more complex forms, can permeate faster through national borders redistributing food aggressively, utilizing the perishable food window effectively, making seamless communications across the globe, and providing great value in terms of traceability, scalability and reachability.

3. Algorithms and Methodology

The flesh and bones of the proposed Modified Food Donor to Receiver Matching with Chronological Acceptance (mFDRM-CA) mechanism is similar to that of the FDRM-CA mechanism [1], since, the former inherits all the procedures of the latter. The modifications that differentiate the proposed mechanism from the existing one are two folds. Firstly, volunteer assignment for donations has been modified for a better matching performance by the mechanism. Secondly, an improved incentive module has been augmented to the mFDRM-CA matching module to attract higher volunteer participation. We discuss both the alterations in this section.

3.1. Notations and Problem Formulation

The following notations help our formal representation of the problem:

- $T_l\%$ of the original volunteer route distance is the off routing threshold for volunteers as already discussed in the aforementioned paper.
- x is the base amount for incentive calculation for volunteers.
- k is the number of activities forming a sliding window for incentive calculation.
- c is the maximum joining bonus in dollars ($) awarded to any volunteer who joins via an invitation link.
- n is the number of volunteers in the *invitation chain* in which the volunteer who completed the transportation is at the 0^{th} position at one end and its root predecessor, the $(n-1)^{th}$ volunteer who connects the chain to the incentive system is at the other end.
- L is the activity list of the n volunteers in the aforementioned invitation chain.

Volunteer availability is the limiting factor when it comes to the performance of the matching module. Due to steep fluctuations in the same based on various factors, the matching mechanism may not be able to produce best fit matches for the available surplus. Our aim is to propose such an incentive mechanism that provides hierarchical incentives so as to encourage volunteer invitation based promotion and participation while discouraging attempts to game the system for personal benefits. We also modify the matching mechanism to optimize volunteer utilization for improved surplus mobility.

3.1.1. The Enhanced Matching Module

In the existing FDRM-CA mechanism, volunteers who have their routes starting close to the donation were considered for assignment to the donor. This was followed by optimising the choice of volunteer based on several factors such as food type, expiry date, volunteer vehicle details, etc. While the optimisation process remains the same with the proposed mechanism, the volunteer pool considered for assignment is enhanced considerably by altering a key condition check. The mFDRM-CA mechanism considers all those volunteers for the donation for whom not only the route start location is

close to the donor, but also those volunteers for whom the donor is anywhere along the entire route of the volunteer. This creates a broader pool for donor-volunteer matching as depicted in Figure 1. Post volunteer assignment, the eligible receivers are selected as in the FDRM-CA mechanism and the volunteer route updated as shown in Figure 2. This alteration in the volunteer pool consideration incurs constant cost both with respect to time and space but generates far better matches for the agents. This is due to the fact that there are now more volunteers to choose from for each available donation resulting in a higher surplus food mobility.

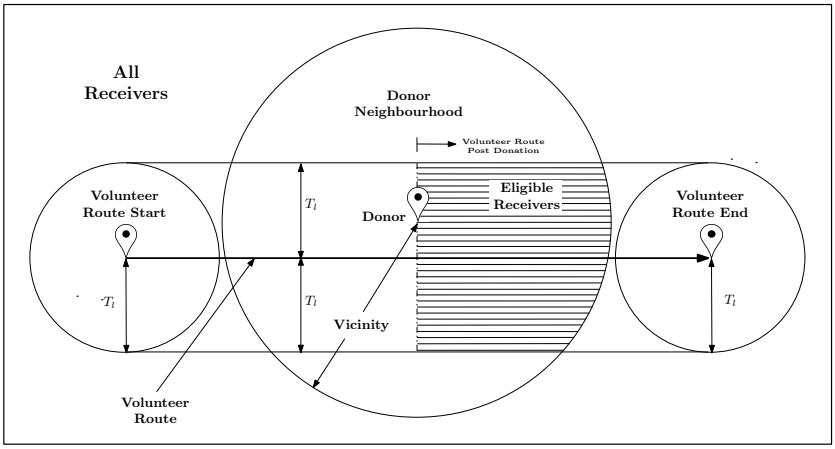


Figure 1: The mFDRM-CA mechanism considers volunteers having the donor location along their routes before matching optimally.

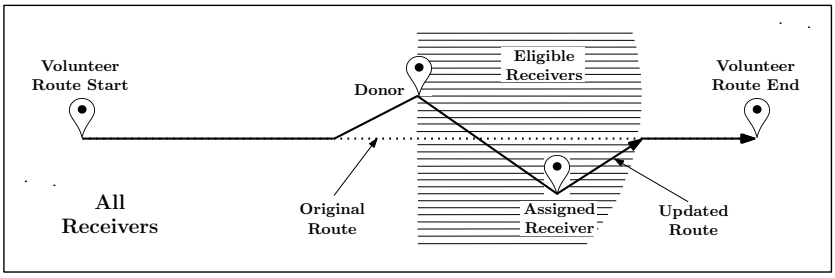


Figure 2: The updated route of the volunteer post match generation and match acceptance by the involved agents.

3.1.2. The Incentive Module

As previously stated, the mFDRM-CA mechanism coordinates with an added incentive module to handle volunteer incentive schemes. The overview of the incentive module along with the Client side user interface is already presented [2]. However, the incentive mechanism presented in the same is susceptible to identity duplication attacks and implement solutions based on limiting the volunteer chain length. This solution discourages volunteer word of mouth promotion and thereby participation. We present two incentive mechanisms that are resistant to identity duplication attacks and encourage volunteer word of mouth promotion as well.

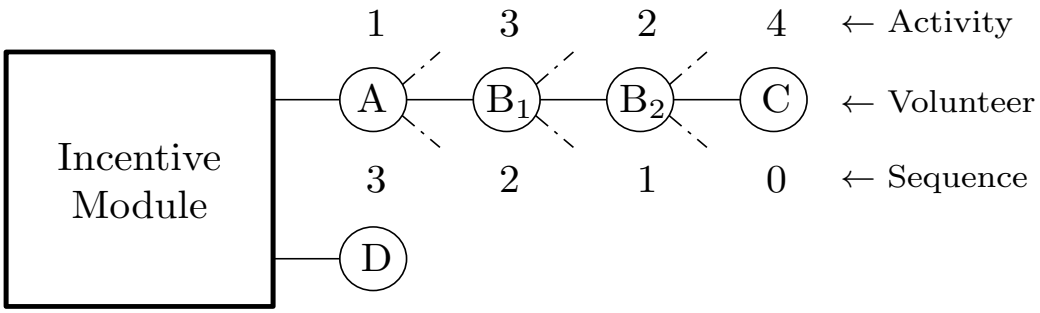
3.1.3. Incentive Calculation

Here, we use the incentive scheme put forward by the MIT team that solved the Defense Advanced Research Project Agency (DARPA) network challenge as discussed in [46]. However, in our scenario this scheme cannot be deployed as it is. Therefore, we make some modifications to the incentive scheme to adapt it to our requirements. We first briefly discuss the initial MIT developed scheme followed by the modifications.

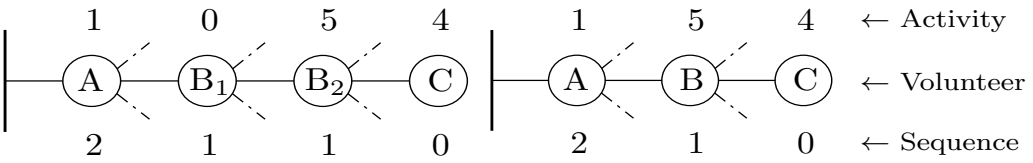
The initial MIT developed scheme used incentives to draw in more workforce via crowdsourcing. Figure 3(a) shows a typical volunteer structure. Volunteers can recruit more volunteers to join the system through them creating a tree like hierarchical structure. For example, in Figure. 3(a), A is the parent of B_1, B_1 is the parent of B_2, and B_2 is the parent of C. If C delivers a surplus, C receives $\$x$, B_2 receives $\$\frac{x}{2}$, B_1 receives $\$\frac{x}{4}$, and A receives $\$\frac{x}{8}$. Thus, volunteer payouts, when numbered with 0 for the volunteer who delivers the surplus, to $n-1$ for the volunteer directly connected to the incentive module, is given by $\frac{x}{2^i}$ for the i^{th} volunteer. We get the total incentive disbursed as:

$$I_{Tot} = \sum_{i=0}^{n} \frac{x}{2^i} < \sum_{i=0}^{\infty} \frac{x}{2^i} = 2x. \tag{1}$$

However, we have a drawback in this scheme. If a person creates a duplicate identity and invites the second identity from the first one, the person gains. This is the case with A in Figure 3(a) where B has two identities, B_1 and B_2, that get $\$\frac{x}{4}$ and $\$\frac{x}{2}$, respectively, as incentives. Thus, *any* person can gain from *any* number of duplicate identities making the volunteer chains long. There are many modifications to encourage shorter chains. Although



(a) Initial structure with multiple volunteer identities.



(b) Activity aggregation. (c) Duplicate identity merger.

Figure 3: A typical volunteer arrangement based on the incentive module to demonstrate the module operation.

effective in reducing the chain length, these modifications effectively negate the most important aim of the crowdsourcing scheme which is to recruit more volunteers. Herein fits our proposed modifications. These modifications to the initial incentive scheme are two folds. The first one handles duplicate volunteer identities and the second one handles new volunteer joining incentives.

3.1.4. Duplicate Identity Management

Here we deal with the fact that all volunteers are profit maximizing agents and will create duplicate identities to game the system. To discourage the duplication of identity and also to encourage participation of the volunteers, we introduce a multiplicative factor, *participation*, while calculating volunteer incentives. This *participation* is calculated as follows.

1. Use the last k activities as the sliding activity window for incentive calculation. Here k is a hyperparameter.
2. Compute a_i as the i^{th} volunteer's activity in the last k activities of the invitation chain of the volunteer who performs the surplus delivery.
3. Now, we calculate the participation of each volunteer i towards the last k activities in this invitation chain in either one of the following two

ways. We shall discuss the merits of each method later.

- **The Volunteer Oriented Incentive Disbursal (VOID) method:** This method tries to offer maximum benefits to the volunteers. While it penalizes identity duplication, it fails to do so under certain conditions that we will discuss later on. In this method, we calculate the participation of the volunteer as follows:

$$p_i^{VOID} = \frac{a_i}{\sum_{j=0}^{i} a_j} \tag{2}$$

- **The System Oriented Incentive Disbursal (SOID) method:** This method tries to offer maximum benefits to the system. It always penalizes for identity duplication. In addition, it penalizes increasingly as the number of duplicate identities increase. Participation is calculated for this method as follows:

$$p_i^{SOID} = \frac{a_i}{\sum_{j \in L} a_j} \tag{3}$$

In the given scenario, the incentives that are generated as a result of the VOID scheme are as given in Table 1. Let us take the case of B_2, who was entitled to an incentive of $\$\frac{x}{2^1}$. Here, a sliding window of $k = 15$ activities has been applied. Since, in the invitation chain of C, the total number of activities is less than the sliding window value (i.e., $4 + 2 + 3 + 1 = 10 < 15$), the window value defaults to $k = 10$. Participation of B_2 is calculated as $\frac{2}{4+2} = \frac{1}{3}$. This way, the final incentive of B_2 becomes $\$\frac{x}{2^1} \times \frac{1}{3} = \$\frac{x}{6}$. We continue calculating incentives of other volunteers in a similar way. Note that the participation of both B_2 and B_1 are the same at $\frac{1}{3}$. Even then their final incentives are different with the volunteer identity having the smaller sequence number getting a higher incentive. This shows that agents with multiple identities will always want to have all their activities in the identity with the lowest sequence number as in 3(b). This is evident from the incentives generated for B with misreporting ($\$\frac{x}{6} + \$\frac{x}{12} = \$\frac{x}{4}$) is less than that after activity aggregation ($\$\frac{5x}{18}$) as shown in Table 2. That will automatically result in no incentives for the identities having higher sequence numbers and no participation. *Furthermore, we merge the identities with*

zero activities with the immediate neighbour with a lower sequence till an identity with a non-zero activity is reached as in 3(c). This results in the removal of distinct sequence numbers for identities having no participation to ensure that their predecessors are not pushed down the sequence number and deprived of their rightful incentive amount. Therefore, the incentive distribution system is resistant to duplicate identities and encourages greater volunteer recruitment. Later on, we discuss certain special conditions under which this resistance may fail.

A similar situation is observable for the SOID scheme and the incentives resulting from the given scenario is shown in Table 3. The same sliding window of $k = 15$ activities has been used here. Let us check for B_2 who now has a participation of $\frac{2}{4+2+3+1} = \frac{1}{5}$, and gets an incentive of $\$\frac{x}{10}$. Similarly, B_1 has a participation of $\frac{3}{4+2+3+1} = \frac{3}{10}$, and gets an incentive of $\$\frac{3x}{40}$. If now, B does all the activities in B_2, then B_2 has a new participation of $\frac{5}{4+2+3+1} = \frac{1}{2}$, and gets an incentive of $\$\frac{x}{4}$ as in Table 4. We see that this incentive for honesty ($\$\frac{x}{4}$) is more than that of identity duplication ($\$\frac{x}{10} + \$\frac{3x}{40} = \$\frac{7x}{40}$). Thus, volunteer B gets motivated to be honest. Also, since in both the schemes the sequence number of A changes to 2, A gets double the incentive amount in this setup when B is honest as that when B is not. In general, when all volunteers are honest, the incentive that any predecessor of dishonest volunteers get is $I_{i+1} = 2^d \times \frac{x}{2^{i+1}}$ where d is the total number of duplicate identities of the dishonest volunteers.

It is to be noted that the VOID mechanism cannot always discourage the volunteers from identity duplication. One such arrangement is when the activities of the volunteers are incremental, starting from the 0^{th} volunteer who delivers the surplus. However, the SOID mechanism always penalizes volunteers for identity duplication in an increasing fashion with the increment in the number of duplicate identities. However, this comes at a cost. The volunteer incentives that the SOID mechanism offers is almost always less than that offered by the VOID mechanism. We present both the mechanisms and leave the choice of selecting one of them to the implementation environment requirements.

3.1.5. Budget Feasibility

From Equation 1, we know that the incentive scheme used in the DARPA red balloon challenge disbursed a maximum total incentive of $\$2x$, where $\$x$ is the base amount for incentive calculation. We compare the VOID and the SOID mechanisms against this scheme to prove its budget feasibility.

Seq.	Volunteer	Raw Incentive ($)	Activity	Participation	Final Incentive ($)
0	C	$x/2^0$	4	$\frac{4}{4} = 1$	x
1	B_2	$x/2^1$	2	$\frac{2}{4+2} = 1/3$	$x/6$
2	B_1	$x/2^2$	3	$\frac{3}{4+2+3} = 1/3$	$x/12$
3	A	$x/2^3$	1	$\frac{1}{4+2+3+1} = 1/10$	$x/80$

Table 1: VOID incentives with misreporting volunteers as shown in Figure 3(a) using $k = 15$.

Seq.	Volunteer	Raw Incentive ($)	Activity	Participation	Final Incentive ($)
0	C	$x/2^0$	4	$\frac{4}{4} = 1$	x
1	B_2	$x/2^1$	5	$\frac{5}{4+5} = 5/9$	$5x/18$
1	B_1	$x/2^1$	0	$\frac{0}{4+5+0} = 0$	0
2	A	$x/2^2$	1	$\frac{1}{4+5+1} = 1/10$	$x/40$

Table 2: VOID incentives after volunteer activity aggregation as shown in Figure 3(b) using $k = 15$.

Seq.	Volunteer	Raw Incentive ($)	Activity	Participation	Final Incentive ($)
0	C	$x/2^0$	4	$\frac{4}{4+2+3+1} = 2/5$	$2x/5$
1	B_2	$x/2^1$	2	$\frac{2}{4+2+3+1} = 1/5$	$x/10$
2	B_1	$x/2^2$	3	$\frac{3}{4+2+3+1} = 3/10$	$3x/40$
3	A	$x/2^3$	1	$\frac{1}{4+2+3+1} = 1/10$	$x/80$

Table 3: SOID incentives with misreporting volunteers as shown in Figure 3(a) using $k = 15$.

Lemma 1. *Total incentive disbursed by the VOID mechanism is always less than $2x where x is the base amount for incentive calculation.*

Proof. The total incentive disbursed by the VOID mechanism is:

Seq.	Volunteer	Raw Incentive ($)	Activity	Participation	Final Incentive ($)
0	C	$x/2^0$	4	$\frac{4}{4+5+0+1} = 2/5$	$2x/5$
1	B_2	$x/2^1$	5	$\frac{5}{4+5+0+1} = 1/2$	$x/4$
1	B_1	$x/2^1$	0	$\frac{0}{4+5+0+1} = 0$	0
2	A	$x/2^2$	1	$\frac{1}{4+5+0+1} = 1/10$	$x/40$

Table 4: SOID incentives after volunteer activity aggregation as shown in Figure 3(b) using $k = 15$.

$$
\begin{aligned}
I_{Tot}^{VOID} &= \sum_{i=0}^{n} \frac{x}{2^i} \times \frac{a_i}{\sum_{j=0}^{i} a_j}, \\
&= \frac{x}{2^0} \times \frac{a_0}{\sum_{j=0}^{i} a_j} + \sum_{i=1}^{n} \frac{x}{2^i} \times \frac{a_i}{\sum_{j=0}^{i} a_j}, \\
&< x + \sum_{i=1}^{n} \frac{x}{2^i} \times \frac{a_i}{\sum_{j=0}^{i} a_j}, \\
&= x + x \times \sum_{i=1}^{n} \frac{1}{2^i} \times \frac{a_i}{\sum_{j=0}^{i} a_j}, \\
&< x + x, \\
&= 2x. \qquad (4)
\end{aligned}
$$

Thus, we see that the total incentive that is disbursed using the VOID mechanism, namely, I_{Tot}^{VOID}, is always less than $\$2x$.

□

Lemma 2. *Total incentive disbursed by the SOID mechanism is always less than $\$2x$ where x is the base amount for incentive calculation.*

Proof. For this proof we can argue in similar lines as the proof for the VOID mechanism. The total incentive disbursed in the SOID mechanism will be:

$$
\begin{aligned}
I_{Tot}^{SOID} &= \sum_{i=0}^{n} \frac{x}{2^i} \times \frac{a_i}{\sum_{j=0}^{n} a_j}, \\
&= \frac{x}{2^0} \times \frac{a_0}{\sum_{j=0}^{n} a_j} + \sum_{i=1}^{n} \frac{x}{2^i} \times \frac{a_i}{\sum_{j=0}^{n} a_j}, \\
&< x + \sum_{i=1}^{n} \frac{x}{2^i} \times \frac{a_i}{\sum_{j=0}^{n} a_j}, \\
&= x + x \times \sum_{i=1}^{n} \frac{1}{2^i} \times \frac{a_i}{\sum_{j=0}^{n} a_j}, \\
&< x + x, \\
&= 2x. \qquad (5)
\end{aligned}
$$

Therefore, the total incentive that is disbursed using the SOID mechanism, I_{Tot}^{SOID}, is also always less than $\$2x$.

□

3.1.6. Word of Mouth Encouragement

Here, we address the issue that new volunteers may wish to bypass the joining link sent to them by other volunteers and decide to join the system directly, robbing their inviting volunteers of their incentives. We here distribute an one time joining incentive when a new volunteer joins through an invitation from another volunteer. This incentive is calculated as follows.

1. The incentive is generated and distributed on the first activity of the new volunteer.
2. The incentive amount per volunteer is capped at $\$c$, another hyperparameter.

3. The total incentive amount is distributed equally between the parent and the child volunteers.
4. The total incentive amount is the difference between the maximum cumulative possible incentive for one activity ($\$2x$) and the actual cumulative incentive distributed. For the two incentive disbursal methods this value will be different.

   - **For the VOID mechanism:** Total joining incentive is

$$I_{Join}^{VOID} = \sum_{i=0}^{\infty} \frac{x}{2^i} - \sum_{i=0}^{n} \frac{x}{2^i} \times \frac{a_i}{\sum_{j=0}^{i} a_j},$$

$$= 2x - \sum_{i=0}^{n} \frac{x}{2^i} \times \frac{a_i}{\sum_{j=0}^{i} a_j}. \tag{6}$$

   - **For the SOID mechanism:** Total joining incentive is

$$I_{Join}^{SOID} = \sum_{i=0}^{\infty} \frac{x}{2^i} - \sum_{i=0}^{n} \frac{x}{2^i} \times \frac{a_i}{\sum_{j \in L} a_j},$$

$$= 2x - \sum_{i=0}^{n} \frac{x}{2^i} \times \frac{a_i}{\sum_{j \in L} a_j}. \tag{7}$$

Thus, both the parent and the child receive half of the total joining incentive amount. This ensures that both the volunteers are interested in volunteer invitations instead of going around and joining the system directly. In addition, since the incentive is generated and distributed on the first activity of the child volunteer, it ensures that the new volunteer is active after joining. The capping amount ensures that there is still scope for charity, as in the initial scheme by the MIT students, or savings, as the requirement may be.

Lemma 3. *Working in a chain is always more profitable than working individually.*

Proof. A volunteer V can join the incentive scheme in any of the positions directly attached to the system out of A, C or D as shown in Figure 3. To

prove this lemma for V, we define the utility function of the volunteer as follows:

$$\begin{aligned} u_V &= u_{individual} + u_{chain}, \\ &= p_0 \times x + \sum_{i>0} p_i \times \frac{x}{2^i}, \\ &= (p_0 + d) \times x, \text{ where } d = \sum_{i>0} p_i \times \frac{1}{2^i}. \end{aligned} \tag{8}$$

Here, p_0 is the participation of volunteer V when working individually, and p_i $(i > 0)$ is the participation for V when the volunteers in the invited chain of V work individually. If V does not invite any volunteer and decides to work individually, then V has utility defined by $u_V = p_0 \times x$ for each activity. Whereas, if V decides to invite more volunteers and work in a chain, the new utility is defined by $u_V = (p_0 + d) \times x$ which is more than $p_0 \times x$ for $d > 0$ accounting for the activities of the invited volunteers as well. Thus, it is evident that a volunteers makes more profit working in a chain than individually. □

3.1.7. A Deeper Thought into the Incentive Mechanisms

The abstract idea of these incentive mechanisms can be generalised to work against sybil attacks on such incentive based systems. Often such systems disburse agents with some reward in exchange of their efforts. These systems are attacked by malicious users or programs what mimic authentic identities to siphon out disproportionate amounts of reward depriving the rightful users of the same, thereby, crashing the system down. Our generalised system can counter such an attack by multiplying the reward amount by a factor $f \leq 1$ that depends on some metric(s) of the agents so that the incentive amount for malicious identities are nullified. This neutralises the sybil attack and stops the malicious identities from gaming the system.

3.2. Proposed Mechanism

The Modified Food Donor to Receiver Matching with Chronological Acceptance (mFDRM-CA) mechanism is proposed for matching donors to receivers, if possible, via volunteers. It inherits all the algorithms of the FDRM-CA mechanism [1]. It, however, has two distinct modifications to enhance its efficiency. One is while the algorithm checks for volunteers for a donation. This enables volunteers to be assigned donation pick-ups from any location

along their route instead of only from near their start location as previously. This affects only a condition check in the algorithm and is therefore omitted here. Although a minor change, it greatly affects the efficiency of the matching process by availing the donors a larger pool of volunteers from which to choose. The other modification is the addition of an improved incentive module so as to attract a higher volunteer participation. As previously, this module works with the matching module to stabilize the availability of volunteers. The algorithms for these methods are provided in this section.

The matching algorithm (Algorithm 1) does three things in parallel. Firstly, it calls the incentive module. Secondly, it starts collecting agent requests in parallel. Thirdly, it starts matching the available requests in parallel. In this third parallel work, it retrieves available donors and receivers and updates their preferences according to the availability of the agents. Thereafter, each donor is selected for assigning volunteers. *All volunteers who have this donor close to their route up to a maximum off routing of T_l% of their total travel distance are pooled together.* This volunteer pool selection is the pivotal change that makes this algorithm perform far better than its predecessor. This performance upgrade is glaringly visible under restricted volunteer availability. The best fit volunteer is then selected for this donor from that pool as per the donation shelf life and the available receiver locations. Now, for each receiver meal request, a donor meal is assigned as per the availability[1].

Algorithm 2 (the VOID mechanism) and Algorithm 3 (the SOID mechanism) are incentive modules. Both work by calculating the activities of volunteers in the volunteer chain with a successful delivery. This activity is calculated in a moving window of k activities. The positions of the volunteers start with 0 for the one who delivers the surplus, and ends with $n-1$ for the one directly attached to the incentive module as in Figure. 3(a). Each volunteer is assigned a proportionate incentive as per the mechanism calling it (VOID or SOID) before calling Algorithm 4 for calculating the joining bonus.

Algorithm 4 checks whether this delivery is the first surplus delivery for the 0^{th} volunteer. If so, it provides the 0^{th} volunteer, and its parent, the 1^{th} volunteer with the joining bonus.

[1]For finer grained details on the matching module please refer to our previous work [1].

Algorithm 1: mFDRM-CA()

```
do in parallel                                              // Call incentive module.
    call VOID(x, c, n, k, L) / SOID(x, c, n, k, L).
do in parallel
    Collect fresh agent requests.
do in parallel                                              // Match requests.
    foreach request do
        Sort requests into perishable and non-perishable.
    Get available donors.
    Get available receivers.
    Update donor preferences.
    Update receiver preferences.
    foreach donor do
        Get available volunteers having this donor around the route
          up to a maximum tolerance of T_l% of the total travel
          distance of the volunteer.
        Assign volunteer by optimizing transportation requirements.
    foreach receiver do
        foreach requested meal do
            Match meal request with available meal from donor.
    return Matches
```

4. Algorithm Analysis

We present the analysis and the various desirable properties of the mFDRM-CA matching and incentive modules in this section.

4.1. Correctness

Lemma 4. *mFDRM-CA works correctly.*

Proof. The proposed mFDRM-CA mechanism inherits all the algorithms of the FDRM-CA algorithm [1] and is different from the same by only two modifications as we already discussed. However, due to this similarity, the correctness proofs remain the same for the mFDRM-CA mechanism as well.

Algorithm 2: VOID(x, c, n, k, L)

$I \leftarrow \Phi$ // Initialize incentive array for n volunteers.
$totAct \leftarrow 0$ // Initialize activity counter.
$totIncentive \leftarrow 0$ // Initialize total incentive.
$A \leftarrow \textbf{sort}(L)$ // Sort activities reverse chronologically.
$cutoffTime \leftarrow A[k].Timestamp$ // Get timestamp of k^{th} activity.
for $i \leftarrow 0$ **to** $n - 1$ **do** // Each volunteer from delivery agent to root.
    $actWin \leftarrow 0$ // Initialize sliding window volunteer activity.
    foreach $activity \in A[i]$ **do** // Activity is in last k activities.
        if $activity.Timestamp \geq cutoffTime$ **then**
            $actWin = actWin + 1$ // Volunteer activity count.
    $totAct = totAct + actWin$ // Total activity in k activity window.
    $I[i] = I[i] + \frac{x}{2^i} \times \frac{actWin}{totAct}$ // Incentive generated for i^{th} agent.
    $totIncentive = totIncentive + I[i]$ // Total incentive disbursed.
$J \leftarrow 2x - totIncentive$ // Amount for joining bonus.
call JOIN(c, A, I, J) // Calculate volunteer joining bonus.

Algorithm 3: SOID(x, c, n, k, L)

$I \leftarrow \Phi$ // Initialize incentive array for n volunteers.
$totIncentive \leftarrow 0$ // Initialize total incentive.
$A \leftarrow \textbf{sort}(L)$ // Sort activities reverse chronologically.
$cutoffTime \leftarrow A[k].Timestamp$ // Get timestamp of k^{th} activity.
$totAct \leftarrow \sum_{cutoffTime} A$ // Initialize activity counter.
for $i \leftarrow 0$ **to** $n - 1$ **do** // Each volunteer from delivery agent to root.
    $actWin \leftarrow 0$ // Initialize sliding window volunteer activity.
    foreach $activity \in A[i]$ **do** // Activity is in last k activities.
        if $activity.Timestamp \geq cutoffTime$ **then**
            $actWin = actWin + 1$ // Volunteer activity count.
    $I[i] = I[i] + \frac{x}{2^i} \times \frac{actWin}{totAct}$ // Incentive generated for i^{th} agent.
    $totIncentive = totIncentive + I[i]$ // Total incentive disbursed.
$J \leftarrow 2x - totIncentive$ // Amount for joining bonus.
call JOIN(c, A, I, J) // Calculate volunteer joining bonus.

Algorithm 4: JOIN(c, A, I, J)

```
if A[0] == 1 then                                  // New user incentive.
    joinBonus = min(J/2, c)                        // Joining bonus.
    I[0] = I[0] + joinBonus                        // Child volunteer.
    I[1] = I[1] + joinBonus                        // Parent volunteer.
return I                                           // Volunteer incentive amount.
```

Thus, to prove the correctness of the proposed mechanism, we need to only prove the same for these two modifications.

The first modification is while the algorithm checks for a volunteer for the transportation of a donation. As this only modifies a location based condition check, it takes constant time as previously. Thus, the main matching module works correctly.

To prove the correctness of the incentive module using both the VOID and the SOID mechanisms, we use the loop invariant technique [47]. The following loop invariant is used:

> At the beginning of the i^{th} iteration, the $(i-1)^{th}$ volunteer's incentive is already calculated.

Initialization: Before the first iteration of the loop, there are no volunteers and the invariant is trivially satisfied.

Maintenance: At any iteration i, the general incentive and the joining bonus is calculated for the i^{th} volunteer. Thus, at the beginning of the next iteration the invariant is maintained.

Termination: At termination, when $i = 0$, each of the n volunteers have their incentives calculated upholding the invariant. This proves that mFDRM-CA works correctly. □

4.2. Strategyproofness

Definition 1. *Strategyproofness* under these settings is defined as the fact that the volunteers can never gain by misreporting. That is, even if a volunteer creates multiple identities to gain incentives on them, the total incentive on all the identities taken together will always be less than the incentive that the volunteer would get on a single identity doing the same amount of activity without identity duplication.

For a volunteer B with a unique identity, the utility function is given by:

$$u_B = u_{individual} + u_{chain}. \tag{9}$$

If the volunteer B misreports and creates multiple identities, the utility of each of these identities is given by the generalized equation for the lth identity:

$$\hat{u}_B^l = u_{individual}^l + u_{chain}^l. \tag{10}$$

Thus, the combined utility of the volunteer B using multiple identities is given by:

$$\hat{u}_B = \sum_l \hat{u}_B^l \tag{11}$$

For strategyproofness condition, we need to have:

$$\hat{u}_B \leq u_B \tag{12}$$

Lemma 5. *mFDRM-CA is strategyproof for all agents using the SOID mechanism.*

Proof. While the matching module is already proved to be strategyproof for donors and receivers [1] and the incentive module has nothing to do with them, all we are left to prove is that the incentive module is strategyproof for volunteers while the SOID mechanism is used. To game the system, volunteers can resort to using multiple identities (IDs) inviting one from the other before recruiting new volunteers. This only results in the distribution of activities of the defaulting volunteers over their different IDs. We already have the utility of the volunteer B in Figure 3 as:

$$u_B = u_{individual} + u_{chain}. \tag{13}$$

Where $u_{individual} = x \times p_0$ is the amount for the volunteer's individual activity. Since, our incentive scheme is dependent on volunteer activity at each ID, it multiplies the raw incentive with a factor derived from the activity count of the ID. We here focus on the volunteer's variable incentive that arises from the activity of the chain given by:

$$u_{chain} = \sum_{i>0} p_i \times \frac{x}{2^i}. \tag{14}$$

Here, i (> 0) is the sequence number taking different values for different activities by the volunteers invited by B. Here, we have B making multiple identities B_1, B_2 and has invited B_2 from B_1. Now B distributes $t > 0$ ($t = t_1 + t_2$) tasks among these two identities with t_1 tasks done in B_1 and t_2 tasks done in B_2. Assuming that C did a successful delivery, the rewards of B_1 and B_2 will be given by:

$$u_{B_2} = \frac{t_2}{a_c + t} \times \frac{x}{2^1}, \tag{15}$$

$$u_{B_1} = \frac{t_1}{a_c + t} \times \frac{x}{2^2}. \tag{16}$$

Where a_c is the activity of volunteer C in the k activity sliding window. The truthful reward for B would be:

$$u_B = \frac{t}{a_c + t} \times \frac{x}{2^1}. \tag{17}$$

Adding Equation 15 and Equation 16, we get the incentive that B gets by being dishonest:

$$\begin{aligned}
\hat{u}_B &= \frac{t_2}{a_c + t} \times \frac{x}{2^1} + \frac{t_1}{a_c + t} \times \frac{x}{2^2}, \\
&= \frac{1}{2} \times \frac{t + t_2}{(a_c + t)} \times \frac{x}{2^1}, \\
&= \frac{1}{2} \times \frac{t}{a_c + t} \times \frac{x}{2^1} + \frac{1}{2} \times \frac{t_2}{a_c + t} \times \frac{x}{2^1}, \\
&= \frac{1}{2} \times u_B + \frac{1}{2} \times \frac{t_2}{a_c + t} \times \frac{x}{2^1}, \\
&< \frac{1}{2} \times u_B + \frac{1}{2} \times u_B, \\
&= u_B.
\end{aligned}$$

This means that while the volunteer would have gotten a greater incentive (u_B) with all activities on the identity that joined latest, now the volunteer

receives a smaller incentive ($\hat{u}_B$) due to distributing the activities over multiple IDs. Thus, a misreport can only result in a loss, making mFDRM-CA used with the SOID mechanism strategyproof for volunteers, and thereby all agents. □

4.3. Pareto-Optimality

Lemma 6. *mFDRM-CA is Pareto-optimal for donors.*

Proof. We use mathematical induction for this proof. Let us assume that mFDRM-CA is not Pareto-optimal and that there exists another algorithm OPT that matches agents Pareto-optimally. The base condition is trivially satisfied for zero iterations. Now in the i^{th} induction step, say both the algorithms have performed equally until now and the matching produced by them till this step is the same and is given by M_i. In the $(i+1)^{th}$ step, mFDRM-CA matches the available donors with the most preferable receivers amongst those still available for matching and produces M_{i+1}. If the OPT mechanism produces any matching in this step that is different from M_{i+1}, it is not Pareto-optimal. Thus, by the Principle of Mathematical Induction, the final match M^{OPT} will not be Pareto-optimal. This is a contradiction to our assumption. Therefore, our initial assumption that mFDRM-CA is not Pareto-optimal is not true. In other words, mFDRM-CA produces Pareto-optimal matching $M^{mFDRM-CA}$. □

4.4. Real-Time Operation

Lemma 7. *mFDRM-CA produces real time results.*

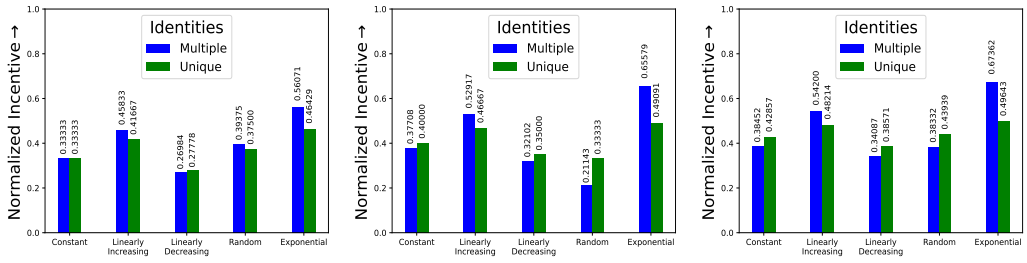
Proof. It is intuitive that the proposed mFDRM-CA matching module has the same time complexity as that of the unmodified one. This happens due to the fact that we replaced the volunteer pool selection process with a better one having a constant time complexity. However, the proposed mechanism has two modules working simultaneously. To calculate the time complexity of the whole mechanism we have the following to consider:

- The matching module takes $O(n^3)$ as previously discussed [1].
- The incentive module takes $O(kn) = O(n)$ as k is a small constant ($k \ll n$).

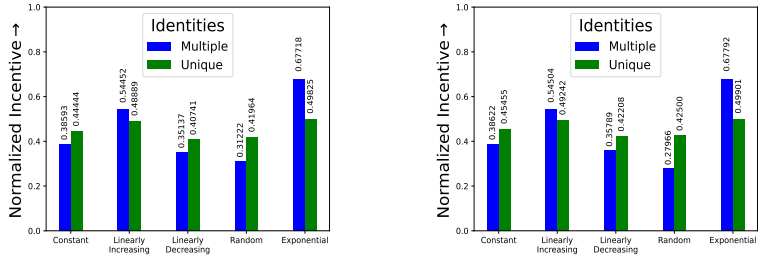
where n is the number of volunteer agents and k is the number of activities for the sliding window calculation of incentives. Thus, the time complexity is capped at $O(n^3)$ making it work in real time. □

5. Results

Figure 4, Figure 5 and Figure 6 present the simulation results of the proposed mechanism against the existing mechanism. Figure 4 contrasts the incentives of a volunteer with multiple identities against a single identity when using the VOID mechanism for incentive disbursal. Similarly, Figure 5 contrasts the incentives of a volunteer with multiple identities against a single identity when using the SOID mechanism for incentive disbursal. In both Figure 4 and Figure 5 the X-axis represents the *activity pattern* which is the pattern formed by the numbers of activities performed by the n volunteers of the volunteer invitation chain in the k-activity window. In Figure 6, volunteer and receiver availability have been expressed in terms of multiples of donor availability ($\times Donors$). Figure 6 contrasts the matching modules of the proposed and the existing modules while varying the availability of volunteers.

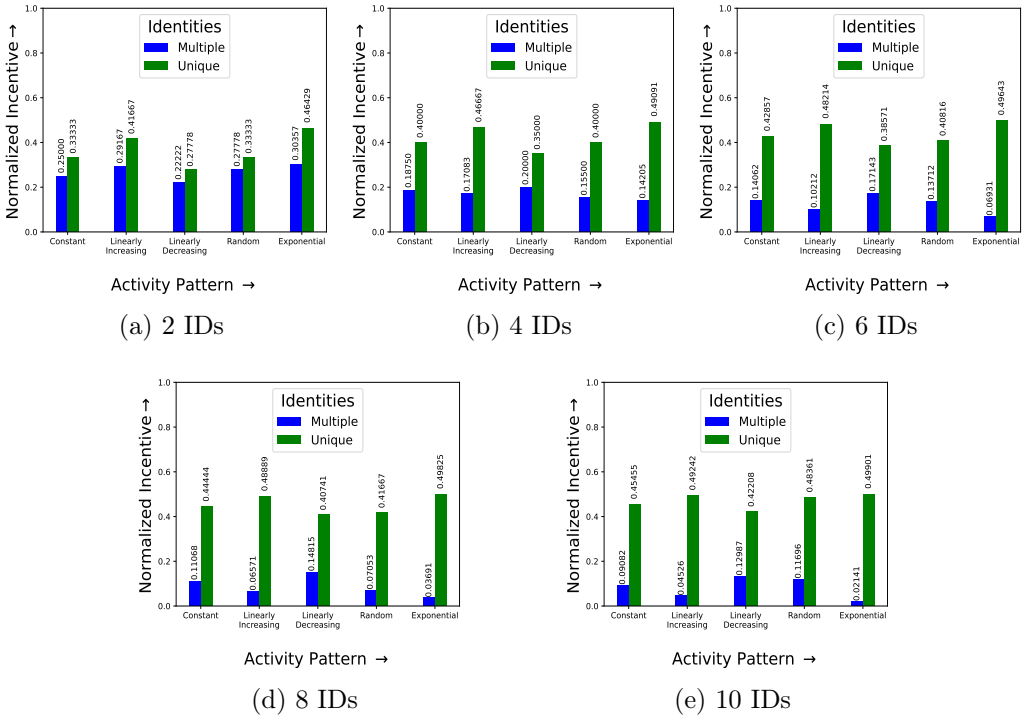


(a) 2 IDs (b) 4 IDs (c) 6 IDs



(d) 8 IDs (e) 10 IDs

Figure 4: Contrasting the incentives of a volunteer with multiple identities for the VOID mechanism.



(a) 2 IDs (b) 4 IDs (c) 6 IDs

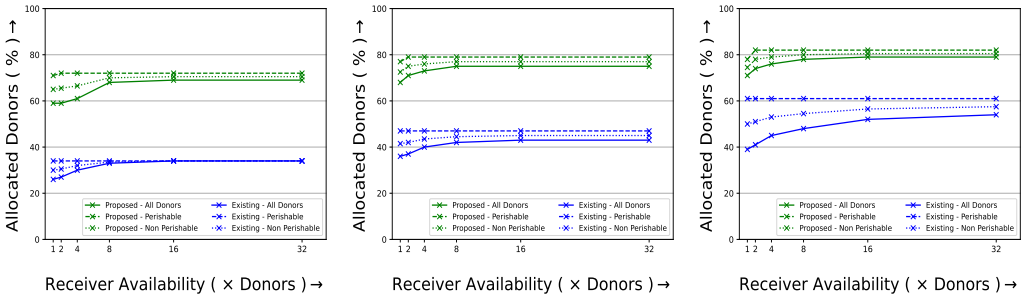
(d) 8 IDs (e) 10 IDs

Figure 5: Contrasting the incentives of a volunteer with multiple identities for the SOID mechanism.

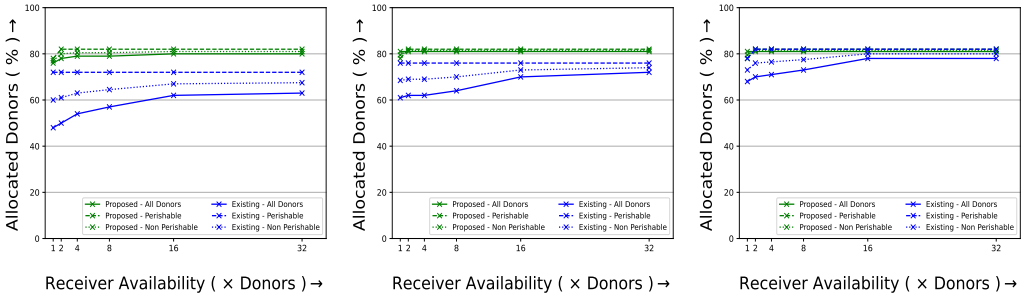
5.1. Setup

For the simulation, we have used real data taken from a real life smart city context, namely, we have used the OPEN DATA BARCELONA at `https://opendata-ajuntament.barcelona.cat/data/en/dataset/est-cadastre-carrecs-us` and cast it to our simulation settings using Python libraries. The simulations were carried out for 200 donations and proportionate receivers and volunteers as relevant for each graph. Operation territory was set to 500×500 kilometers. An 18 hour operation window was taken from 06:00 hours to 23:59 hours. Both the incentive mechanisms, namely, the VOID and the SOID, were simulated with different levels of identity duplication. Other simulation parameters were kept similar to that of our previous work [1].

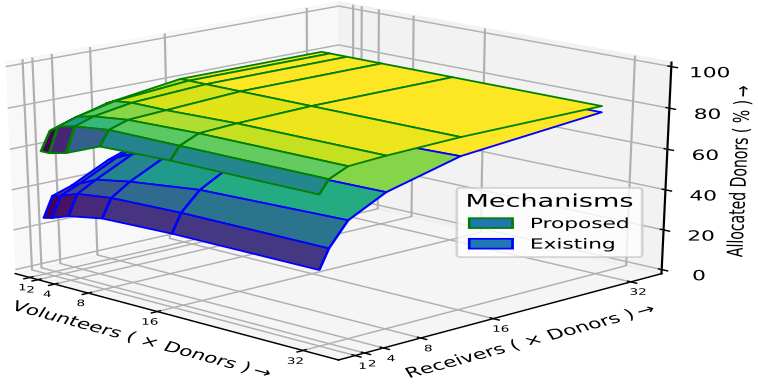
For the VOID mechanism simulation as in Figure 4, we use the following equation for calculating the total incentive of the volunteer having α identities in the system chained to each other.



(a) Volunteers: 1 × Donors (b) Volunteers: 2 × Donors (c) Volunteers: 4 × Donors



(d) Volunteers: 8 × Donors (e) Volunteers: 16 × Donors (f) Volunteers: 32 × Donors



(g) Mechanism saturation.

Figure 6: Simulation results comparing the performances of the existing and the proposed matching mechanisms.

$$I_{Tot}^{VOID} = \sum_{i=1}^{\alpha} \frac{x}{2^i} \times \frac{a_i}{\sum_{j=0}^{i} a_j}. \tag{18}$$

For the SOID mechanism simulation shown in Figure 5, we use the following equation to calculate the total incentive of the volunteer on α identities in the incentive chain.

$$I_{Tot}^{SOID} = \sum_{i=1}^{\alpha} \frac{x}{2^i} \times \frac{a_i}{\sum_{j=0}^{n} a_j}. \tag{19}$$

In the matching module, we use the following equation to determine the availability of volunteers that rule the matching process where β is the multiplier controlling the current availability of volunteers for matching. Here $|V|$ and $|D|$ are the numbers of available volunteers and donors, respectively.

$$|V| = \beta \times |D|. \tag{20}$$

Under these settings we evaluate our proposed mechanism against the existing one by varying the values of $\alpha = \{2, 4, 6, 8, 10\}$ and $\beta = \{1, 2, 4, 8, 16, 32\}$.

5.2. Analysis

Figure 4 presents the incentives that the the VOID mechanism offers to a volunteer through multiple identities against that obtained with a single identity. Figure 5 presents the incentives under the same settings using the SOID mechanism. It is to be observed that while a volunteer can never gain using multiple identities in the SOID mechanism, it is not the same for the VOID mechanism. In fact, it can be observed that for *linearly increasing* and *exponentially increasing* as well as occasionally for the *random* activity patterns, multiple identities provide more incentive to the volunteer. However, the SOID mechanism never lets the volunteer gain by using multiple identities. As a matter of fact, it penalizes the volunteer increasingly with increasing number of duplicate identities.

Figure 6(a) through Figure 6(f) contrast the effects of the availability of volunteers and receivers on the performance of the proposed and the existing mechanisms. Although the existing mechanism performs nearly as well when

volunteer availability is very high, it is evident from these results that the proposed mechanism performs far better at lower availability of volunteers. The proposed mechanism also maintains similar allocations of agents in the perishable and non perishable food categories. Perishable food items still get a higher precedence over the non perishable ones when matching.

Figure 6(g) presents the speed with which the two mechanisms reach saturation in terms of matching the agents for the generated agent request data. We observe that the proposed mechanism reaches its maximum matching potential earlier than the existing mechanism. This clearly represents the potential of the proposed mechanism to perform better under lower volunteer and receiver concentrations. In addition, the inclusion of the incentive module results in an increase in the availability of volunteers. This in turn shifts the current availability of volunteers to the higher end of the scale further increasing the matching performance of the mechanism.

6. Discussion

The above results confirm the following claims presented in this paper:

- The mFDRM-CA matching module shows better performance due to the fact that the matching algorithm assigns volunteers to donors along the route in addition to donors lose to the start location of the route.
- The mFDRM-CA incentive module attracts more volunteer participation tipping low volunteer availability scenarios to higher ones resulting in better match generation performance.
- The mFDRM-CA, using the SOID mechanism, is strategyproof for the volunteers and encourages higher volunteer activity as well by rewarding volunteers having higher activity with higher incentives.
- The mFDRM-CA stabilizes the availability of volunteers over time through the disbursal of incentives. As this is the greatest factor in improving surplus mobility, it contributes to the better performance of the mechanism.

7. Conclusion

Surplus food distribution is one of the best available solutions to the global menace that is wastage of edible food. The throwing away of the portion of

food that is perfectly consumable is countered by surplus distribution either through individuals or through communities. ICT and IoT boost the performance of such food movement activities by making high speed coordination possible among the involved agents. The existing mechanism provides a base for individuals and startups in this area to begin with their operations. However, it suffers with performance issues under lower volunteer availability. To complicate the situation further, the availability of volunteer is shown to be fluctuating rapidly.

The proposed mFDRM-CA mechanism offers a solution to these challenges by modifying the matching mechanism and introducing an incentive module to inspire higher volunteer participation. The modification in the matching process allows for a greater volunteer pool per donation resulting in a higher overall surplus mobility. The incentive module generates incentive for each successful volunteering activity when opted for the same. This encourages greater volunteer participation and ensures volunteer availability for the demanding routes and trips. It also dampens the fluctuation of the availability of the volunteers over time. For the simulation, we have used real data taken from a real life smart city context, namely, we have used the OPEN DATA BARCELONA at `https://opendata-ajuntament.barcelona.cat/data/en/dataset/est-cadastre-carrecs-us` and cast it to our simulation settings using Python libraries. As the participation in the noble food rescue operation widens, the mFDRM-CA mechanism will be an important tool leading to better agent matching performance and higher overall participant satisfaction. This ultimately ensures a sustainable approach towards dealing with the food wasted related issues of today.

Our work encourages the volunteers to remain active. Otherwise, they forfeit their incentive amounts. A competitive participation from the volunteers will keep the surplus distribution movement active as the availability of volunteers keeps steady over time. However, it is to be noted that although our work takes into account the number of surplus deliveries of the volunteers, it does not account for the distance travelled by the volunteer while delivering the surplus. It may so happen that the distance travelled by an intercity volunteer is far more than the volunteer who has more number of trips during the same time window. This effort need to be rewarded so that surplus distribution can truly go across borders. This we declare as our future scope of research.

Funding: Fatos Xhafa's work is supported by Project "Optimizing Carshar-

ing and Ridesharing Mobility in Smart Sustainable Cities" (grant 21S09355-001) of the Ajuntament of Barcelona and the Fundació "la Caixa" under the framework of the Barcelona Science Plan 2020-2023.

Data Availability: For the simulation, we have used real data taken from a real life smart city context, namely, we used the OPEN DATA BARCELONA at `https://opendata-ajuntament.barcelona.cat/data/en/dataset/est-cadastre-carrecs-us` and cast it to our simulation settings using Python libraries.

Competing Interests: The authors have no competing interests to declare.

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