Abstract—In this paper, we consider a dense vehicular communication network where each vehicle broadcasts its safety information to its neighborhood in each transmission period. Such applications require low latency and high reliability, and thus, we exploit non-orthogonal multiple access to reduce the latency and to improve the packet reception probability. In the proposed scheme, the BS performs semi-persistent scheduling and allocates time-frequency resources in a non-orthogonal manner while the vehicles autonomously perform distributed power control. We formulate the centralized scheduling and resource allocation problem as a multi-dimensional stable roommate matching problem and develop a novel rotation matching algorithm to solve it. Simulation results show that the proposed scheme outperforms the traditional orthogonal multiple access scheme in terms of the latency and reliability.

I. INTRODUCTION

With the rapid development of vehicular networks, a growing number of applications have emerged to improve the driving experience. Among various applications, safety critical services play a vital role, supported by the vehicle-to-everything (V2X) communications [1]. To achieve low-latency and high-reliability (LLHR) for the V2X services, the Long Term Evolution (LTE) networks have been considered as a very promising solution by exploiting the device-to-device (D2D) communications [2], [3]. However, the existing LTE networks are based on the orthogonal multiple access (OMA) techniques and have not fully utilized the limited spectrum resources. This may lead to the severe data congestion and low access efficiency in a dense vehicular network.

To handle the challenges of access collisions and massive connectivity, non-orthogonal multiple access (NOMA) schemes have been introduced as a potential solution for 5G wireless networks, which allow users to access the channel non-orthogonally [4]. Capable of achieving high overloading transmission over limited resources, NOMA provides a new dimension for V2X services to resolve the congestion problem, especially in a dense environment, thereby reducing the latency.

In this paper, we consider the V2X broadcast scenario [5] where every vehicle needs to update its safety information to the neighborhood in each transmission period. Each period consists of multiple time slots and the transmitter-receiver (Tx-Rx) selection needs to be determined for each slot such that all vehicles can update their safety information in at least one slot during this period. Sub-channel allocation in each time slot is performed to manage the co-channel interference caused by the non-orthogonal nature in NOMA. Moreover, to successfully decode the superposed received signals, an efficient real-time power control method should be applied by the users. New challenges are thus posed in the design of scheduling and resource allocation schemes.

To tackle these challenges, we propose a NOMA-based mixed centralized/distributed (NOMA-MCD) scheme for cellular V2X broadcasting. The centralized semi-persistent scheduling (SPS) [5] is performed by the BS where the Tx-Rx is selected and the time and frequency resources are allocated periodically in every a few transmissions. For the BS, Tx-Rx selection and resource allocation problem can be formulated as a non-linear integer programming problem to maximize the packet reception probability of the network. The distributed power control is then performed by each user.

To resolve such a combinatorial optimization problem on Tx-Rx selection and resource allocation, we decouple it into two multi-dimensional stable roommate (MD-SR) matching problems [6], [7], where the vehicles and time slots/sub-channels are considered as two sets of “students” and “rooms” such that multiple “students” can occupy the same “room”. We then develop a novel rotation matching algorithm for the MD-SR problem, which converges to a stable matching. Simulation results show that our proposed NOMA-MCD scheme performs better than the traditional OMA scheme.

Few works have discussed how to improve the performance of the safety critical applications from a NOMA-based perspective. The most related ones [8]–[10] are listed as below with the assumptions of fixed Tx-Rx selection or transmit power. In [8], a distributed scheme for the coordination of D2D broadcast transmission has been presented based on OMA. In [9], resource management for D2D unicast safety-critical vehicular communications has been discussed. In [10], a centralized sub-channel allocation scheme involving several D2D broadcast groups underlaying cellular network has been proposed by utilizing a greedy algorithm.

1A vehicle is called a Tx user if it broadcasts in a time slot, otherwise, a Rx user.
The rest of this paper is organized as follows. In Section II, we describe the system model and propose the NOMA-MCD scheme. In Section III, we formulate the centralized SPS of the BS as a packet reception probability maximization problem and solve it by utilizing the matching theory. In Section IV, an iterative signaling control scheme is designed for the distributed power control problem of the Tx users. Simulation results are presented in Section V, and finally, we conclude the paper in Section VI.

II. SYSTEM MODEL AND SCHEME DESIGN

In this section, we present the system model of the cellular V2X broadcasting system and propose a NOMA-based cellular V2X broadcasting scheme to reduce access collisions.

A. Scenario Description

Consider an urban V2X broadcast system as shown in Fig. 1. In every transmission period consisting of multiple time slots, each of N vehicles broadcasts safety-critical information\(^2\) to its neighborhood in at least one time slot. The pedestrians always act as Rx users in each time slot. Direct data transmission between neighboring users is achieved by the D2D communications. The available bandwidth is divided into K sub-channels for transmitting.

Due to the dense topology of the network, when more than one Tx user (e.g., Tx user 1 and Tx user 2 in Fig. 1) are assigned the same time-frequency resources, collision may occur for those Rx users (e.g., Rx user 1) locating in the overlapping region of two adjacent Tx users’ communication ranges. To reduce the probability of collision as well as the transmission delay, NOMA is then considered such that one sub-channel can be occupied by multiple Tx users simultaneously [11]. Each conflicting Rx user, such as Rx user 1 in Fig. 1, utilizes the SIC technique to decode the received superposed signals, thereby avoiding the collision.

B. NOMA-based Collision Avoidance

1) Channel Model: Based on the NOMA scheme, the received signal of Rx user \(m\) over subchannel \(k\) in time slot \(i\) (the \(i\)th time slot of a transmission period) is

\[
y^{(i)}_{m,k} = \sum_{j \in N^i_m} \gamma_{j,k} H^{(i)}_{j,m,k} s_j^{(i)} + n^{(i)}_{m},
\]

where \(N^i_m = \{1 \leq j \leq N | d^{(i)}_{j,m} \leq r\}\) denotes the index set of users within Rx user \(m\)'s communication range of interest, i.e., a disk of radius \(r\). \(\gamma_{j,k}\) is a binary variable to indicate whether user \(j\) is a Tx user transmitting over subchannel \(k\) in time slot \(i\), \(H^{(i)}_{j,m,k}\) is the transmit power of Tx user \(j\), \(H^{(i)}_{j,m,k}\) denotes the channel coefficient of subchannel \(k\) between Tx user \(j\) and Rx user \(m\) in time slot \(i\), \(s_j^{(i)}\) represents the transmitted symbol, \(n^{(i)}_{m} \sim CN(0, \sigma^2_n)\) is the additive white Gaussian noise (AWGN) for Rx user \(m\) with variance \(\sigma^2_n\).

In equation (1), the channel coefficient can be expressed as

\[H^{(i)}_{j,m,k} = h^{(i)}_{j,m,k} g^{(i)}_{j,m},\]

where \(h^{(i)}_{j,m,k}\) and \(g^{(i)}_{j,m} = \beta d^{(i)}_{j,m}^{-\alpha}\) denote fading and distance-dependent pathloss, respectively, with \(d^{(i)}_{j,m}\) representing the distance between two users \(j\) and \(m\) in time slot \(i\).

2) SIC Decoding: The transmit power of the links corresponding to the conflicting Rx users will be carefully adjusted according to the NOMA principle [11]. Each conflicting Rx user \(m\) decodes the received signals in a decreasing order of channel gains. For any conflicting Rx user \(m\), the achievable rate obtained from Tx user \(j\) over subchannel \(k\) in time slot \(i\) can be expressed as:

\[
R^{(i)}_{j,m,k} = \log_2 \left( 1 + \frac{p^{(i)}_{j,k} H^{(i)}_{j,m,k} g^{(i)}_{j,m}}{1 + \sum_{j' \in S^{(i)}_{j,m,k}} p^{(i)}_{j',k} \rho^{(i)}_{j',m,k}} \right),
\]

where \(p^{(i)}_{j,m,k} = |H^{(i)}_{j,m,k}|^2 / \left( \frac{n^{(i)}_{m}}{\sigma^2_n} \right)^2\) represents the SNR of the Tx user \(j\)–Rx user \(m\) link, and \(S^{(i)}_{j,m,k}\) is the set of active Tx users causing interference when Rx user \(m\) decodes the signal of Tx user \(j\).

3) Criteria for Successful Decoding: When any conflicting Rx user \(m\) receives signals from multiple Tx users, two criteria for Rx user \(m\) to successfully detect the signal \(x_j\) received from Tx user \(j\) over subchannel \(k\) in time slot \(i\) are: i) the signals of other Tx users with higher channel gains than Tx user \(j\) are successfully decoded first; ii) the rate threshold of Tx user \(j\) is satisfied, i.e., \(R^{(i)}_{j,m,k} \geq \bar{R}_{th}\).

The above criteria can be mathematically expressed as

\[
\prod_{j' \in N^i_m \setminus S^{(i)}_{j,m,k}} \gamma_{j',k} (R^{(i)}_{j',m,k} - \bar{R}_{th})^+ = 1,
\]

where \((\cdot)^+\) is a signed function and \(j' \in N^i_m \setminus S^{(i)}_{j,m,k}\) implies that the channel gain between active Tx user \(j'\) and Rx user \(m\) is higher than that between Tx user \(j\) and Rx user \(m\).

C. NOMA-based Mixed Centralized/Distributed Scheme

Based on the above non-orthogonal manner of reducing the collision, we aim to design a scheme where each user
can successfully broadcast the safety information to as many neighboring users as possible while satisfying the latency requirement. We then propose a NOMA-MCD scheme consisting of the following two phases: 1) centralized Tx-Rx selection and time-frequency resource allocation of the BS; 2) distributed power control of the users.

1) Centralized Tx-Rx Selection and Time-frequency Resource Allocation of the BS: To avoid the nonnegligible UL latency in the traditional dynamic scheduling, centralized SPS is considered in which the BS only updates the resource allocation scheme periodically. To be specific, the BS determines the Tx-Rx selection and subchannel allocation of each time slot at the beginning of each SPS period. The resource allocation scheme then remains unchanged within each transmission period of the same SPS period. The centralized SPS can be performed by the BS based on the users’ relative position information obtained from the periodic user broadcasting.

2) Distributed Power Control of the Users: The NOMA scheme requires prior knowledge of the users for SIC decoding such as the real-time CSI, which is hard for the BS to obtain due to the mobility of the vehicles. Distributed real-time power control of the users is then performed after the centralized SPS. The resource allocation scheme then remains unchanged within each transmission period of the same SPS period. The centralized SPS can be performed by the BS based on the users’ relative position information obtained from the periodic power control of the users by the BS.

III. NOMA-BASED CENTRALIZED SEMI-PERSISTENT SCHEDULING

In this section, we formulate the centralized Tx-Rx selection and time-frequency resource allocation of the BS as a packet reception probability (PRP) maximization problem and then solve it by utilizing the matching theory.

A. Problem Formulation

Due to the time-varying nature of CSI in the vehicular network, we adopt only partial CSI in the centralized SPS, i.e., $H_{i,m,k}^{(i)} = g_{j,m}^{(i)}$. To improve the reliability of the network, we try to alleviate the probability of collision such that fewer retransmissions are required, which in turn reduces the latency. Since the collision reduction can improve the PRP of the network, we then aim at maximizing the PRP of each transmission period, which is proportional to the total number of signals successfully decoded by all Rx users.

To be more general, we adopt the logistic function instead of the indicator function in (3) to depict the PRP. The probability that the signal of Tx user $j$ is successfully decoded by Rx user $m$ over subchannel $k$ in time slot $i$ is given as:

$$U_{j,m,k}^{(i)} = \gamma_{j,k}^{(i)} \left(1 - \gamma_{m,k}^{(i)}\right) \prod_{j' \in N(i) \backslash j} \frac{\gamma_{j',k}^{(i)}}{1 + e^{\eta [R_{j',m,k}^{(i)} - R_{th}^{(i)}]}}$$ (4)

where $\eta$ is the slope parameter of the logistic function.

Based on the above discussion, the Tx-Rx selection and time-frequency resource allocation problem of the BS in one transmission period can then be formulated as,

$$\max_{\gamma_{j,k}^{(i)}} \sum_{i=1}^{T_v} \sum_{k=1}^{K} \sum_{m=1}^{N} \sum_{j \in N(m)} U_{j,m,k}^{(i)}$$ (5)

s.t. $\sum_{k=1}^{K} \left(\gamma_{j,k}^{(i)} + \gamma_{j',k}^{(i)}\right) \leq 1, \{j, j'\} \in \{1 \leq j, j' \leq N \mid d_{j,j'}^{(i)} < r\}$

$1 \leq \sum_{k=1}^{K} \gamma_{j,k}^{(i)} \leq T_{max}$

$\sum_{j \in N(i)} \gamma_{j,k}^{(i)} - \gamma_{m,k}^{(i)} \leq K_u$

$\gamma_{j,k}^{(i)} \in \{0, 1\}, 1 \leq j \leq N, 1 \leq k \leq K, 1 \leq i \leq T_v$. (5d)

Constraint (5a) denotes that any two users within each other’s communication range cannot be Tx users at the same time since they will never receive each other’s message while transmitting due to the half duplex nature. For the sake of user fairness, at most $T_{max}$ time slots are allocated to a Tx user in one transmission period as expressed in constraint (5b). Considering the decoding complexity of SIC, we assume that each subchannel can be assigned to at most $K_u$ Tx users with overlapping communication disks simultaneously as shown in constraint (5c).

B. Matching Algorithm Design

To solve the above problem, we consider the users and the time slots/subchannels as two disjoint sets of “students” and “rooms” such that multiple "students" can share the same "room". As shown in constraint (7a), the time scheduling is considered prior to sub-channel allocation for the users and the time-frequency resources cannot be considered as a whole. We then formulate the optimization problem in (5) as two MD versions of the SR problem.

1) Matching Problem Formulation for the Tx-Rx Selection and Time Scheduling: We formulate the Tx-Rx selection and time scheduling problem as a two-sided matching between the sets of users and time slots. If a user is matched with one time slot, we say that it acts as a Tx user in this time slot; otherwise it acts as a Rx user in this time slot. Denote the set of users as $\mathcal{N}$ and the set of time slots in one transmission period as $\mathcal{T}$. Mathematically, a matching $\Psi$ is defined as a mapping from the set $\mathcal{N} \cup \mathcal{T} \cup \emptyset$ into itself such that $\Psi(j) \subseteq \mathcal{T}, j \in \mathcal{N}$ and $\Psi(i) \subseteq \mathcal{N}, i \in \mathcal{T}$.

Any two users matching to the same time slot are defined as matching peers. Users $(j, j')$ are defined as a forbidden pair in time slot $i$ if $d_{j,j'}^{(i)} \leq r$, that is, they cannot be matched with this time slot simultaneously due to constraint (5a).

To better describe the interaction between the users, we then investigate how each user selects its matching peers. The key idea is that each user tends to choose those far away from it as its matching peers so that the overlapping part of
their communication disks will be small and the number of conflicting Rx users will decrease. In this way, the potential collision, which can also be referred as cross influence of multiple Tx users, can be reduced. Mathematically, the cross influence on the Rx users brought by any two Tx users $j$ and $j'$ in time slot $i$ can be evaluated by:

$$J_{j,j'}^{(i)} = \begin{cases} \frac{2r - d_{j,j'}^{(i)}}{\varepsilon}, & \text{if } 2r > d_{j,j'}^{(i)}, \\ \varepsilon, & \text{otherwise}, \end{cases}$$

where $-0.1 < \varepsilon < 0$ is small enough. Therefore, the average cross influence brought by user $j$ in time slot $i$ is given by

$$Q_{j}^{(i)} = \begin{cases} \frac{1}{|\Psi(i)|+1} \sum_{j \in \Psi(i)} J_{j,j'}^{(i)}, & \text{if } |\psi(i)| > 1, \\ \varepsilon, & \text{if } |\psi(i)| = 1. \end{cases}$$

The total cross influence with respect to time slot $i$ can then be obtained easily. We refer the matching problem here as a MD-geometric SR problem.

2) Rotation Matching Algorithm for MD-Geometric SR Problem: If there is no matched forbidden pair in the final matching, we then say that it is a feasible solution.

a) Phase 1 – Obtaining a feasible solution: We utilize a greedy algorithm in which each user is assigned with one time slot if the matching problem is solvable. For any unmatched user $j$, the set of available matched time slots is denoted as

$$P_j = \{i \in I_{\text{matched}} | \Psi(i) \cap H_j = \emptyset\},$$

where $I_{\text{matched}}$ is the set of all matched time slots and $H_j$ is the set of users forming forbidden pairs with user $j$. When $P_j = \emptyset$, user $j$ selects an unmatched time slot $i'$. Otherwise, it selects a matched time slot $i^*$ such that it brings the smallest cross influence $Q_j^{(i)}$, i.e.,

$$T_{i^*} = \arg\min_i Q_j^{(i)}.$$

b) Phase 2 – Rotation matching: We introduce the concept of rotation to better describe the interdependency of different users in the MD-geometric SR problem.

Definition 1: Given a matching $\Psi$ obtained from the first phase with a subset of users $\mathcal{N}_s \subseteq \mathcal{N}$ satisfying $|\mathcal{N}_s| = L \geq 2$, a rotation sequence refers to

$$\zeta = (N_s(1), \Psi(N_s(l + 1))), \ldots, (N_s(L), \Psi(N_s(l))),$$

A rotation matching $\Psi_{\mathcal{N}_s,\zeta}^{\text{rot}}$ with respect to rotation sequence $\zeta$ is defined as

$$\Psi_{\mathcal{N}_s,\zeta}^{\text{rot}} = \Psi \setminus \{(N_s(1), \Psi(N_s(1))), \ldots, (N_s(q), \Psi(N_s(q)))\} \cup \zeta.$$

To be specific, a rotation matching is generated in which a subset of users switch their matches in a pre-defined cyclic order shown in (9) while other users remain their matches. Considering the complexity of the algorithm, we set the length of each rotation sequence $L \leq L_{\text{max}}$.

The optimality and validity of one rotation matching are shown below.

Definition 2: Consider a matching $\Psi$ and a subset of users $\mathcal{N}_s \subseteq \mathcal{N}$ with size $L$. For $1 \leq l \leq L - 1$, a rotation matching $\Psi_{\mathcal{N}_s,\zeta}^{\text{rot}}$ is valid if any user $j \in \mathcal{N}_s$ does not form forbidden pairs with any matching peers in $\Psi_{\mathcal{N}_s,\zeta}^{\text{rot}} \setminus \{(\mathcal{N}_s(q), \Psi(N_s(q)))\} \cup \zeta$.

3) Multi-dimensional Stable Roommate Matching for the Sub-channel Allocation: We now extend the above algorithm to solve the sub-channel allocation problem in each time slot. We re-construct the utility function based on (4) to formulate a non-convex integer programming problem, which is much more intractable than the time-user matching problem.

a) Definitions: We observe that the set of Tx users and subchannels can be considered as “students” and “rooms” in an MD SR problem, respectively. Denote the set of the Tx users in each time slot $i$ as $\mathcal{N}_s(i)$, and the set of subchannels as $\mathcal{K}$. In each time slot $i$, a user-subchannel matching $\Phi_i$ is then defined as a mapping from the set $\mathcal{N}_s(i) \cup \mathcal{K} \cup \emptyset$ into itself.
such that $\Phi (j) \subseteq K$ and $\Phi (k) \subseteq N_t^{(i)}$, in which $j \in N_t^{(i)}$, $k \in K$. Each Tx user can match multiple sub-channels and each sub-channel can match multiple Tx users.

b) Utility functions: Different from the geometric utility function in (7), we further evaluate the co-channel cross influence based on the number of successfully decoded signals.

For any Tx user $j$, its utility with respect to subchannel $k$ is defined in (4), i.e., $\sum_{m \in \mathcal{N}_j} U_{j,m,k}^{(i)}$. The optimal rotation matching for a subset of Tx users $\mathcal{N}_s \subseteq N_t^{(i)}$ in time slot $i$ can be rewritten as,

$$ I^* = \arg \max_{1 \leq L \leq L^*} \sum_{j \in \mathcal{N}_s} \sum_{m \in \mathcal{N}_j^{(i)}} \sum_{k \in \Phi_{\mathcal{N}_s \setminus \{j\}} \Phi_N^{(i)}} U_{j,m,k}^{(i)} . $$

With the above definitions, the modified rotation matching algorithm is shown in Table II. In the centralized SPS scheme, the BS performs the above two matching algorithms sequentially. The convergence and stability of these two algorithms can be guaranteed based on Definition 3.

IV. NOMA-based DISTRIBUTED POWER CONTROL

In this section, we address NOMA-based distributed power control in which a power control problem is formulated for each Tx user and the control signaling between the Tx users and Rx users is considered.

To perform SIC decoding, necessary prior knowledge needs to be provided to the Rx users, e.g., the CSI of the intended Tx user – Rx user links, the number and transmit powers of the corresponding Tx users. Therefore, the distributed power control requires information exchange between the Tx users and the Rx users, i.e., the control signaling.

We divide each time slot into one control signaling sub-timeslot and one data transmitting sub-timeslot, in which the control sub-timeslot is divided into several pairs of Tx blocks and Rx blocks for control message exchange between the Tx users and the Rx users. Each pair of a Tx block and a Rx block iteratively works as below:

- **Tx block:** every Tx user $j$ broadcasts a reference signal to its neighborhood containing the transmit power and the frequency resources that it will occupy for the data transmission. The transmit power, $p_j$, is determined based on the feedback sent by the Rx users in the previous block. Each Rx user $m$ obtains its neighboring Tx users’ CSI via the received reference signals.

- **Rx block:** each Rx user $m$ evaluates whether it will successfully decode the coming data messages based on the information obtained from the Tx block. It then calculates the potential co-channel interference to each Tx user $j$ caused by other Tx users and broadcasts the feedback for further processing in the next Tx block.

The power control problem of Tx user $j$ over subchannel $k$ in each Tx block of time slot $i$ can be formulated as below:

$$ \min_{p_{j,k}} p_{j,k}^{(i)} $$

subject to:

$$ \sum_{m \in \mathcal{N}_k} \left[ R_{j,m,k}^{(i)} (p_{j,k}^{(i)}) - R_{th} \right]^+ \geq w_j \left| b_{j,k}^{(i)} \right|, $$

where $P$ is the maximum transmit power of Tx user $j$ over subchannel $k$, $\mathcal{B}_{j,k}^{(i)}$ is the set of Rx users sending feedback to Tx user $j$ during the Rx block over subchannel $k$ in time slot $i$, and $w_j \in [0, 1]$ is a unique weighted value for each Tx user $j$. Constraint (12a) guarantees that the cross interference caused by multiple Tx users can be constrained to a tolerable level. Problem (12) can be solved by utilizing a bisection method.

V. SIMULATION RESULTS

In this section, we consider the urban scenario defined in [5]. The average inter-vehicle distance in the same lane is 2.5s× speed, and the same density/speed in all lanes is adopted [5]. We evaluate the performance of the proposed NOMA-HCD scheme compared with the traditional OMA-based scheme and a NOMA-based geometric greedy algorithm (NOMA-GGA):

- **OMA-based scheme:** each Tx user transmits at maximum power. The Tx-Rx selection is solved by utilizing a greedy algorithm and the graph-based method in [10] is performed in the sub-channel allocation.

- **NOMA-GGA:** we adopt the geometric utility function (7) in the centralized SPS for both time and frequency resource allocation, where a greedy algorithm is adopted. Major simulation parameters are listed in Table III. We consider the length of each scheduling period as 40ms for simplicity here. The number of subchannels is set as 5 in the NOMA case and 10 in the OMA case, respectively.

Fig. 2 illustrates the PRP versus the speed of the vehicles where the communication range of interest is 150m and at most two Tx users share the same sub-channel. In the simulation, we consider a packet successfully received only when the latency requirement is satisfied. We observe that
when the speed increases, the density of users decreases in the network, and thus, there is less potential collision, leading to an increased PRP. Furthermore, the gap between the OMA-based scheme and the NOMA-MCD scheme becomes smaller as the speed grows, indicating that the non-orthogonal manner of resource utilization works better in a dense network.

Fig. 3 presents the latency satisfaction ratio versus the decoding rate threshold. When the speed increases, the decoding rate threshold becomes closer to the required transmission rate for low latency. From Fig. 3, more Tx users can satisfy the latency requirement in the NOMA case compared to the OMA case. This is because the spectrum efficiency of the OMA case is lower than that of the NOMA case, leading to higher transmission delay.

VI. Conclusions

In this paper, we studied the scheduling and resource allocation problem in a cellular V2X broadcasting system. To reduce the access collision and improve the reliability of the network, we proposed a NOMA-based mixed centralized/distributed scheme, in which the time-frequency resources can be fully employed in a non-orthogonal manner by the BS while the dynamic power control along with the iterative control signaling is autonomously performed by the vehicles to achieve a better performance of power domain multiplexing. Simulation results showed that the NOMA-MCD scheme outperforms the OMA-based scheme especially in a dense network.

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