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Green NOMA assisted NB-IoT based urban farming in multistory buildings

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ABSTRACT

In this study, 5G- NB-IoT, enabled smart urban farming framework is presented. In order to maximize the Energy-Efficiency (EE) of NB-IoT enabled sensor network's downlink performance (deployed in urban structure), 5 G promising technology device to device (D2D) communication along with power-domain Non-Orthogonal-Multiple-Access (NOMA) principle were used and studied at two levels, i.e. *NOMA-at- Base Station (BS)* and *NOMA-at-Edge*. In the case of *NOMA-at-BS*, the BS transmits the superimposed signals to the NB-IoT-enabled sensor D2D pairs *(termed as NOMA-D2D approach)*. Whereas in the case of *NOMA at the Edge*, in the group of NB-IoT enabled sensor nodes, the group head will transmit the superimposed signals to other group receiver sensor nodes *(termed as Group-NOMA-D2D approach)*. These suggested solutions, ensure interference-free communication among deployed NB-IoT enabled sensor networks. The proposed approaches were implemented on the NB-IoT sensor network (deployed in balconies of two multistory building structures) and their results were evaluated through simulation. The promising enhancement in terms of sum-rate (32% to 35 %), total-energy efficiency, and fairness factor (1- 0.98) has been achieved using the Group NOMA-D2D approach in comparison to NOMA-D2D and conventional D2D approach. In addition to this, a fuzzy logic-aided solution has also been proposed for NB-IoT enabled sensor network, uplink resource grant, and post allocation resource re-utilization, this, in turn, improved the Quality of Experience (QoE) by 2–14%.

1. Introduction

The arable land per person is declining due to persistent rapid growth in population and urbanization. It is anticipated that by 2050 world population will mount to 9.8 billion, of which ~68% is anticipated to live in urban areas [1]. Consequently, agro land is obliged to shrink in order to provide more land for housing and building. This swift urbanization will endanger food security by further mounting the urban heat island effect. These factors have spurred the development of Zero-acre or urban farming [2]. Urban farming includes farming on the building structures such as roofs, facades, walls, and balconies. Though, urban farming offers multiple advantages, like urban food security, urban waste reduction, and mitigation of deleterious consequences of urbanization on the environment [3]. Yet the challenge of food quality assurance and productivity are a big concern. Thus to ensure, urban food quality and improvement in productivity, controlled environment conditions (CEC) is one of crucial factors. In this concern, researchers have used different techniques to maintain the controlled environment [4,5] to improve productivity and assure food quality. The authors in [6] have proposed a Petri-Net-based hardware-software model for smart urban farming, Authors in [7] have proposed a smart IoT-based hydroponic system for the indoor environment using a Deep Neural Network to ensure CEC. Furthermore, airborne light detection and infrared sensor-based methodology is developed in [8] to identify the possibility of implementation of rooftop greenhouses in urban areas. The authors in [9] proposed a decision-based framework for sustainable urban farming. The authors in [10] have designed an urban agro monitoring model for green infrastructure based on the DASH-7 protocol. The authors in [11] have developed an urban agro monitoring system using 6LoWPAN, for cassava crops to improve the received signal strength and reduce packet loss. The author in [12] analyzed the usage of waste-water utilization for urban farming, to achieve the sustainability goals. The authors in [13] proposed a LoRa based IoT platform to gather, analyze and monitor agro data collected from an urban vegetable garden. The author in [14] proposed a model to determine the area for urban farming and ensure its security using remotely sensed LiDAR data.

The research work discussed in the previous literature reveals that a lot of studies has been carried out related to the different aspect of urban

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Table 1
Proposed scheme comparison with existing schemes.

Ref No.	Description of Algorithm	Approach	Technology used	Parameter Optimized	UL/DL
[4]	Proposed an IoT based Urban agro system to control irrigation system using agro parameter verification	Data analysis	WiFi	Reliability	UL
[7]	Proposed a model to identify the feasible locations for rooftop farming	Feasibility study	Airborne sensor	Productivity of crop	-
[10]	Proposed a wsn for green infrastructure monitoring	Monitoring	DASH-7	NA	UL
[11]	Urban Agro monitoring system to monitor the different parameters like soil moisture, water while ensuring the technical parameter improvement	Routing based	6LoWPAN	RSSI, Packet Loss, LQI	UL
[13]	Proposed an urban agro monitoring model using LoRa	Monitoring	LoRa	Enhance the management of crop	UL
[14]	Land decision-based model for urban farming	Monitoring	LiDAR	Crop productivity	DL
Proposed Approach	**Group NOMA-D2D approach for EE urban farming in the multistory building**	**Group-NOMA**	**NB-IoT**	**Sum Rate, EE, MOS, FF, UL resource allocation**	**DL, UL**

farming, including optimal farm area selection, crop selection, etc. However, very few studies are available related to energy-efficient communication for automated smart urban farming models.

In this paper, two NOMA abetted 5G-NBIoT, based energy-efficient communication solutions, i.e. NOMA-D2D (NDA) and Group NOMA-D2D (GNDA) have been proposed for the smart urban farming model. The novelty of the proposed approaches lies in the fact that these ensure interference-free communication among NB-IoT-enabled sensor networks deployed in urban structures. In order to do the performance analysis of the proposed approaches, two multistory building scenarios were considered. It was found that GNDA outperforms the NOMA-D2D approach. In the comparison of the NOMA-D2D Approach, the Group-NOMA-D2D approach improves the sum rate by 32–35 %, results in achieving an excellent fairness factor in the range of 1 to 0.98. The proposed Group-NOMA-D2D approaches improved the total EE remarkably in comparison to the conventional approach.

Further to optimize the UL resource allocation during the random access process, a fuzzy-based UL resource allocation approach is also presented, this improved the QoE of sensor nodes by 2–14 % (measured in terms of Mean Opinion Score).

1.1. Background and related work

Currently, in all developing and developed countries, the urban farming concept is being used as an alternative agro source. The integration of IoT with urban farming (U-IoT), is consenting U-IoT to become data-driven, protruding to resource-efficient production. However, to do this, Massive Machine type communication (MMTC) either using licensed (NB-IoT,) or non-licensed (ZigBee, Wi-Fi, Z-wave, etc.) technology is used.

In 5 G to support energy-efficient massive low power machine type communication, a relatively new licensed cellular technology, NB-IoT is standardized by 3GPP in Rel-13. It offers long battery life, and for both, downlink (DL) and uplink (UL) communications it utilizes narrow bandwidth of 180 kHz, offers extended coverage. Besides this, it has also low device complexity, offers efficient & reliable connectivity over a wide area [15]. Thus become the leading choice for smart-urban-farming in an outdoor environment. Howbeit due to the narrow spectrum, it endures low capacity and low rate.

Thus to meet the rigorous requirements of massive connectivity, advanced energy-efficient solutions including MIMO, D2D, UDN, multiple access techniques, connecting technologies, etc. have been identified. 5 G promising technology D2D communication aids in direct communication among devices without intervention of the base station (BS) that results in low power consumption and thereby improves the EE. Inspired by the aforementioned potential of D2D, in this paper, the NB-IoT-enabled D2D framework is proposed for EE smart urban farming in multi-story buildings. However, the critical issue involved with the existence of D2D communication in 5 G WCNs is interference among the D2D users. This can be mitigated through optimal resource allocation and power control. Thus apart from invoking D2D, another 3GPP proposed, innovative NOMA technique is recognized as a propitious solution for 5G- MMTC that endorses energy-efficient and spectral efficient network [16,17].

As different from conventional OMA techniques eg. TDMA, FDMA, NOMA could serve multiple users simultaneously via power domain division while using the same resource. Integrating NOMA to NB-IoT enabled D2D communication will tranquilize green 5 G WNs.

The recent pioneer research done related to enhance the performance of the NB-IoT network using NOMA are discussed here. The authors in [18] proposed a heuristic algorithm to increase the connection density of the number of IoT device that can be served in a single slot, leveraging the flexibility of NB-IoT multi-tone subcarrier allocation. The authors in [19] suggested a NOMA-based NB-IoT device clustering algorithm to improve UL communication. The author in [20] proposed a NOMA-based solution that jointly orders superimposed signals and caters the resource allocation, to minimize the NB-IoT network UL transmission and computation latency. The authors in [21] propose to allocate the NB-IoT subcarriers in a non-contiguous manner and used the NOMA principle to allow the set of the device to share the same for UL communication. The author in [22] proposed a stochastic-connectivity-optimization framework to further improve the performance of the conventional NOMA approach, even when channel-state- information available is partial. Further, A matching-game-based algorithm is proposed in [23] to optimally utilize power for superimposed NOMA signals for NB-IoT device communication. The authors in [24] proposed a relay-based NOMA solution to improve the NB-IoT network performance. From the above literature, it has been found that to enhance NB-IoT device network DL performance, the NOMA-D2D approach has not been explored. Thus in this study two power domain-based, NOMA-NB-IoT-D2D and Group-NOMA-NB-IoT-D2D framework-based solutions have been proposed for EE smart urban farming in two different types of multi-story building structures. In addition to this to optimize the uplink grant during the random access process, a *Fuzzy-Logic based algorithm* is also proposed. The proposed Fuzzy-Logic-based algorithm considers multiple parameters including the number of pairs sharing the subchannel, data rate requirement, and application type {T, V, A} for UL resource grant. Table I presents a proposed scheme comparison with the existent literature schemes.

The contributions of the paper are summarized in the next section

1.2. Contribution

The main contributions of the presented study are discussed below:

1 NOMA-D2D & Group-NOMA-D2D based single-cell network is modeled for NB-IoT enabled sensor network, deployed in the balcony of multistory buildings for farming. In particular, based on channel state and data rate requirements BS transmits the superimposed signal to the selection of *NOMA-D2D* pairs, allocated the same

TABLE 2
NOTATIONS.

Symbols	Notations
N	Number of NB-IoT enabled sensors
$\mathfrak{N}$	Set of sensors
$\mathbb{D}$	Set of D2D pairs
$\dot{\mathbb{S}}$	Set of sub-channels
D_m^{BS}	Maximum number of D2D pairs that can share subchannel
G_m	Maximum members in a group can share a subchannel
G_H	Group Head
G_R	Group receivers
$\mathbb{G}$	Set of Group
Sm	Signal transmitted by group head to *m* the receiver node
$\lvert h_{n,q}\rvert^2$	Channel gain of nth D2D pair transmitter and BS over sub-channel q.
$y_{n,q}$	Signal received by n^{th} D2D pair transmitter over subchannel q
$\alpha_{n,q}$	Power channel coefficient of nth D2D pair on subchannel q
P^q	Subchannel q transmitted power
$SINR_{n,q}$	Signal to noise ratio of nth D2D pair receiver, on subchannel q
y_{G_R}	Signal received by the group receiver node
$P_{GH_i}^R$	Power received by Group Head *i* on receiving the signal from BS.
$\mathscr{R}_{n,q}$	Data Rate of nth pair on channel q
$\mathscr{R}_T^q$	Sum Rate of D_m^{BS} NOMA-Pair on channel q
$\beta_{G_{Rn}^i,q}$	Power channel coefficient of nth group receiver on subchannel q
$\lvert h_{G_{R1}^i,q}\rvert^2$	Channel gain between nth Group receiver and Group Head over sub-channel q
$SINR_{n,q}^{G^i}$	Signal to noise ratio at nth group receiver, on subchannel q of group i
$\lvert h_{i,j}\rvert^2$	Channel gain between sensor device i and j
P_d	Device power
ω	Bandwidth for UL allocation
$TR_{\mathbb{G}}^i$	Total throughput during different iterations of Groups
MOS	Mean Opinion Score
$\mathscr{P}_{Total}^{q,GH_{i,j}}$	Group head *i* total power consumed
EE_ND	Total energy efficiency

subchannels. Whereas in the *Group-NOMA-D2D* approach, the Group head (sensor node) transmits the superimposed signal to the group receiver (sensor) nodes.

2 The NB-IoT system EE maximization problem is formulated. The improved EE is achieved via constrained power allocation and with reduced multiple interferences from neighbor devices that ultimately improve the total sum rate of downlink communication. The simulation revealed that Group-NOMA-D2D /NOMA-at-Edge outperforms the NOMA-D2D/NOMA-at-BS.
3 A Fuzzy-logic-based optimal UL resource allocation with a re-utilization scheme is proposed, which results in enriched QoE, evaluated through the mean opinion score (MOS).
4 The proposed NOMA aided NB-IoT approaches are compared with the conventional D2D approach for two considered building types A& B (shown in Appendix).

The paper is organized as follows. Background and the presented work-related literature review are discussed in section I A. Device-to-device preliminary is given in section II. The system model for smart farming and the problem is formulated in Section III. Further in section IV impact of NOMA-SIC on interference bear by NB-IoT sensor network is explained. Following this UL resource allocation using Fuzzy logic is explained in section V, Furthermore, the pseudo-codes for EE maximization using NOMA-based approaches are given in section VI, The result and discussion are given in section VIII. Finally, the paper is concluded in section VIII. The notations used in the paper is given in Table 2

2. Device to device preliminary

D2D communication is one of the 5G competent technology. Certain factors are crucial for D2D communication, such as resource sharing mode selection, communication mode selection, and interference cancellation. For the general procedure of D2D communication two phases can be defined as the Discovery phase and the Communication phase. [25,26]

Discovery phase: During this phase, UE searches for the potential peer in proximity for D2D communication and determines the identification of the founded peer. Number of messages regarding link qualities are exchanged between UEs and UEs and the BS. Once this information is available at the BS, it may serve as the basic input to the mode selection, power control, resource allocation, and actual transmission of information in the communication phase. The *communication phase* includes channel estimation, mode selection.

The discovery of D2D pairs can be done either directly or with network assistance. Based on the level of network assistance, discovery technologies can be fully controlled or loosely controlled. The procedure for both discovery techniques are shown in Fig. 1. Multiple performance metrics can be considered by D2D discovery technologies, such as discovery time, discovery range, energy consumption, resource efficiency, signaling overhead, etc.

Uplink Resources for discovery are allocated using RRC signaling, which consists of the Discovery period information, the number of sub frames that can be utilized for transmission of discovery signals, number of physical resource blocks. Post allocation MAC layer (of D2D pair) determines the radio resource to be used for transmission of discovery information.

Once the device discovery is complete, *resource allocation needs to be performed for data transmission and communication*. Based on spectrum utilization firstly D2D communication can be classified into two types: In-Band and Out-Band. When D2D communication takes place over licensed spectrum it is referred to as in-band communication and on the unlicensed spectrum, it is referred to as out-band communication. Thereafter the mode of resource allocation is selected for D2D communication.

The D2D pair can communicate in either of 3 resource sharing modes:

(1) Cellular mode CM): where the device communicates directly via eNB.
(2) Overlay/Dedicated mode: where 2 devices are allowed to exchange data among themselves without eNB involvement, although eNB allocates the radio resource for D2D transmissions.
(3) Shared/Underlay mode: in this, the radio resources are shared among the cellular and D2D devices.

Fig. 2, shows these different resource-sharing communication modes.

While selecting the best mode the instantaneous channel conditions, interference, and network load are considered.

BS allocates the resource for data transmission to the D2D pair through steps shown in Fig. 3: The Buffer status report procedure is initiated by the device when it wants to transmit data. This is to intimate the eNB about the data awaiting transmission. Before this scheduling request is transmitted. Thereafter the BS either utilizes overlay or underlay resources for allocation.

The key challenges that obstruct the D2D performance are interference, security, and power consumption. To reduce the D2D interference, power control and optimal resource allocation algorithms are used. The prime factor that affects the level of interference is geometry. The geometry defines the mutual distance between the interferer and the prey of the interferer. Since in this study the D2D pairs of NB-IoT enabled sensors deployed in Building are also in close proximity of each other, hence bear high interference. Thereby to alleviate the interference during DL communication, the power domain NOMA principle is used, which in turn improved the energy efficiency of the NB-IoT sensor network.

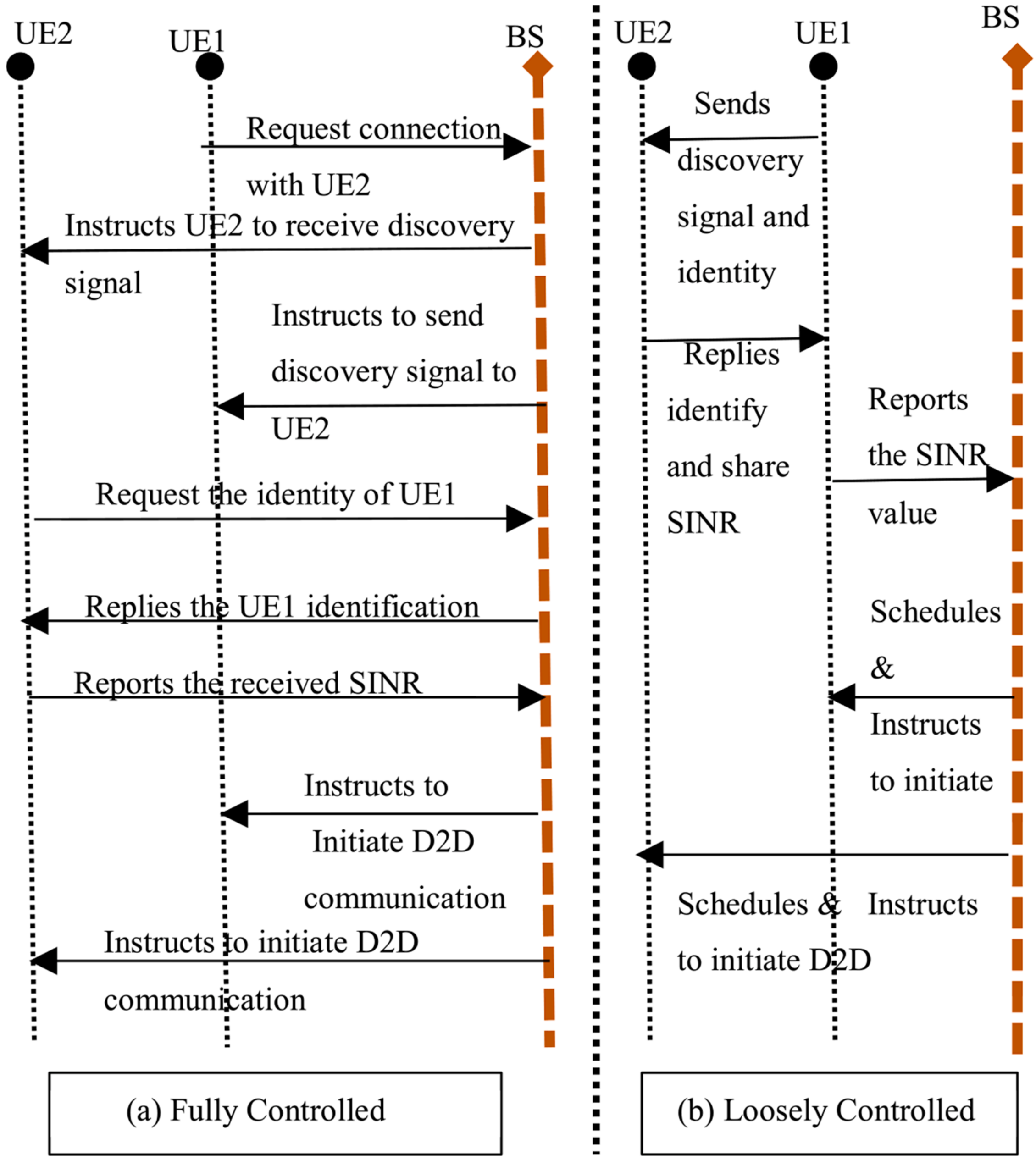


Fig. 1. (a) Fully controlled (b) Loosely controlled Discovery procedure [25].

3. Network model

A detailed description of the model is discussed in this section.

3.1. System description

A single cell downlink transmission scenario is considered, where one eNB communicates with N NB-IoT enabled sensors deployed in the balcony of multistory building structures. The scenario for multistory building structures is depicted in Fig. 4 & Fig 5. The N NB-IoT enabled sensors deployed in each balcony of the apartment of a multistory building and are denoted as $\Re = \{sn_1, sn_2, \ldots\ldots, sn_N\}$.

The complete channel state information of all the sensors is assumed to be available at Base Station (BS)

NOMA at BS: Using the NOMA principle, BS broadcast the superposition of M signals, to a set of M D2D pair symbolized as $\mathbb{D} = \{d_1^{BS}, d_2^{BS}, \ldots\ldots, d_M^{BS}\}$ formed with Inter-Floor pairing or Intra-Floor pairing using power domain division. The setup of the NB-IoT enabled sensor D2D network using Inter-Floor or Intra-Floor pairing scheme is presented in pseudocode-1.

The maximum number of NOMA aided NB-IoT D2D pairs that can share a sub-channel, sc_q, $sc_q \in \dot{\mathbb{S}}$

$$= \{sc_1, sc_2, \ldots, sc_q, .., sc_M\}$$

sc_q, $sc_q \in \dot{\mathbb{S}} = \{sc_1, sc_2, \ldots, sc_q, .., sc_M\}$ be D_m^{BS} formed either by Inter-Floor or Intra-Floor D2D pairing respectively, such that $D_m^{BS} = \{d_1^{BS}, d_2^{BS}, \ldots d_m^{BS}\}$, $D_m^{BS} \subset \mathbb{D}$. The power constraint for each subchannel and BS are given by $\sum_{i=1}^{m} p_{i,q} = P_q$ and $\sum_{n=1}^{M} P_n = P_{BS}$

(*Here pairing depends collectively on distance and channel gain, where channel gain depends on PL which greatly depends on the obstacles through which signal passes such as concrete walls, plants, glass panes, etc.)

NOMA at Edge: Besides this, another ***NB-IoT enabled Group D2D*** scenario is considered. Here Group D2D refers to pair formation

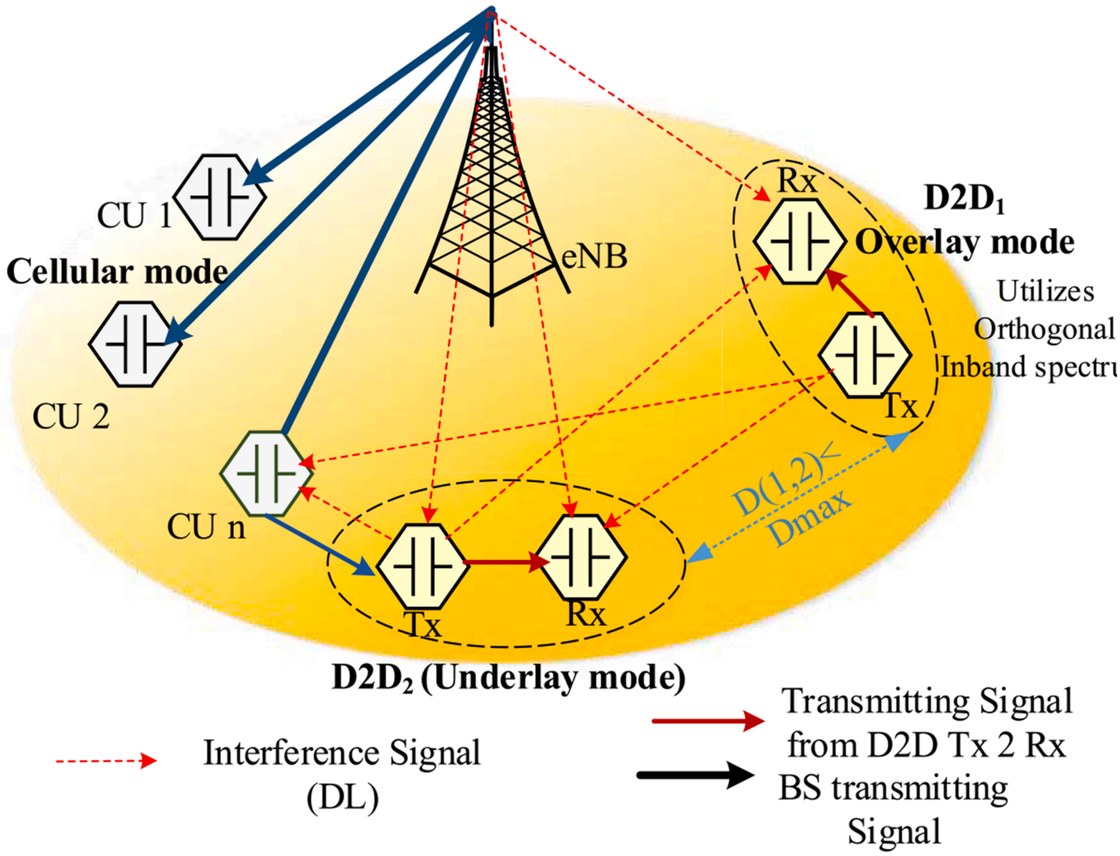


Fig. 2. Resource Sharing Modes and DL interference.

between-group head G_H, and group receiver G_R nodes. The sensor node in a group with optimal channel condition (w.r.t BS) in comparison to other grouped sensor nodes is selected as G_H. A G_H, undergoes traditional cellular communication, by communicating with BS directly. Each G_H is allocated one subchannel each from the set of subchannels $\dot{\mathbb{S}}$. The selected G_H, then communicates with m G_R (group receiver sensor nodes) using power domain NOMA principle. An illustration of NOMA group communication is presented in Fig. 5. A group can have at max G_m members, such that $G_m = \{sn_1, sn_2, \ldots sn_m\}$, $G_m \subset \mathbb{G}$, $\lceil G_m \rceil < N$.

The setup of the NB-IoT enabled sensor Group D2D network using Inter-Floor or Intra-Floor pairing scheme is presented in pseudocode-3.

3.1.1. Assumptions

- In type-A multistory building the transmitted signal fades severely due to concrete wall separation between two floors, thus G_H will communicate with sensor nodes on the same floor. Similarly, in type-B building the G_H will communicate vertically due to the same reason stated above. As shown in Fig. 4 and 5.
- The BS is fixed, located on the roof-top of the tallest building, has high processing power, and endless energy source. All NB-IoT-enabled sensor nodes are assumed to have a continuous power supply.
- BS utilizes an information metric that includes information regarding device location or distance from BS, channel conditions, adaptive modulation coding scheme, the power level that defines the nature of the device, frequency spectrum, application resource demand.
- NB-IoT-sensor-nodes are energy homogeneous and are location-aware. Hence can identify the location of their neighbor nodes.
- In the Group NOMA-D2D approach, the Group Head identified is fixed (as shown in Fig. 5) in this study for both the Type A & B building. Since the sensor once deployed will remain static. Besides this time driven sensing of information is considered, whereby each sensor, sense the balcony farmed area at a fixed rate and it may or may not have information to transfer depending on the information is lower or higher than the threshold value

3.2. Channel model

To determine the channel condition of each NB-IoT enabled sensor device with respect to BS, the Building path loss model is used. Which includes outdoor loss, indoor loss, and the additional loss due to varying incidence of transmitted signals. In this paper, the cost 231 model is used for the evaluation of Building entry path loss., which computes the path loss as follows [27]

$$PL_{out} = 32.4 + 20\ \log(f) + 20\log(d_{3D-out} + d_{3D-in}) \tag{1a}$$

$$PL_p = L_e + LG_e(1 - \cos(\theta))^2 \tag{1b}$$

$$PL_{in} = \beta.d_{3D-in} \tag{1c}$$

$$PL_T = PL_{out} + PL_{in} + PL_P \tag{1d}$$

Here, PL_{out}, PL_{in}, PL_P, θ, f, L_e, LG_e denotes outdoor path loss from BS to terminal device, Indoor loss, Penetration loss, is the angle of incidence, carrier frequency in GHz, wall penetration loss, loss due to varying incidence angle respectively. Further, the distance definition for the device, used for the evaluation.is given in Fig. 6.

As described earlier, D2D pairs will interfere each other, thus to avoid interference NOMA is used. Such that each sub-channel is occupied by multiple NB-IoT D2D pairs (*formed either with Intra or Inter Floor*

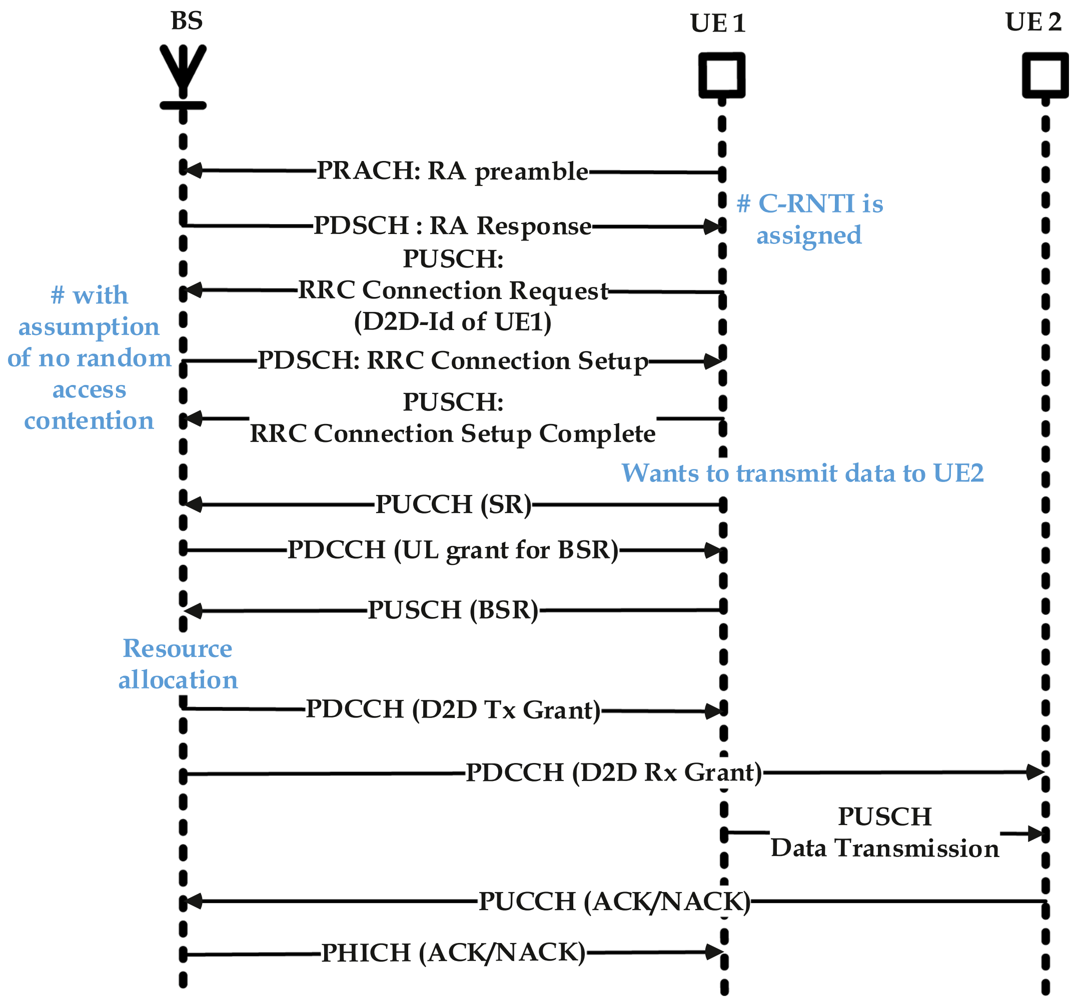
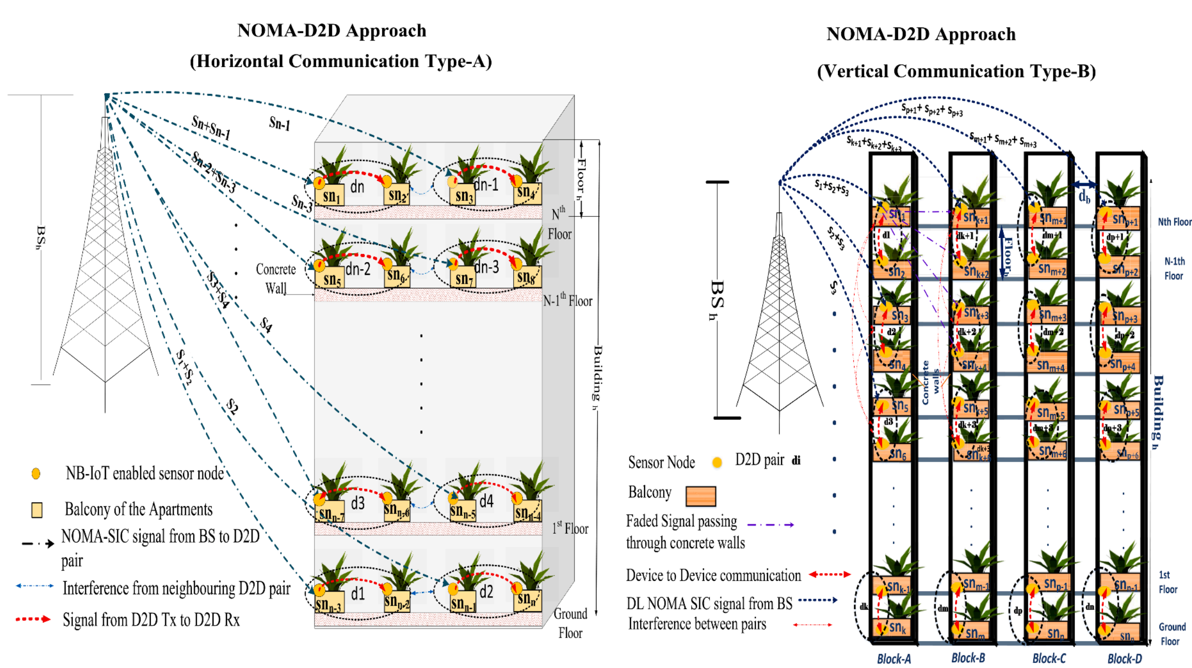
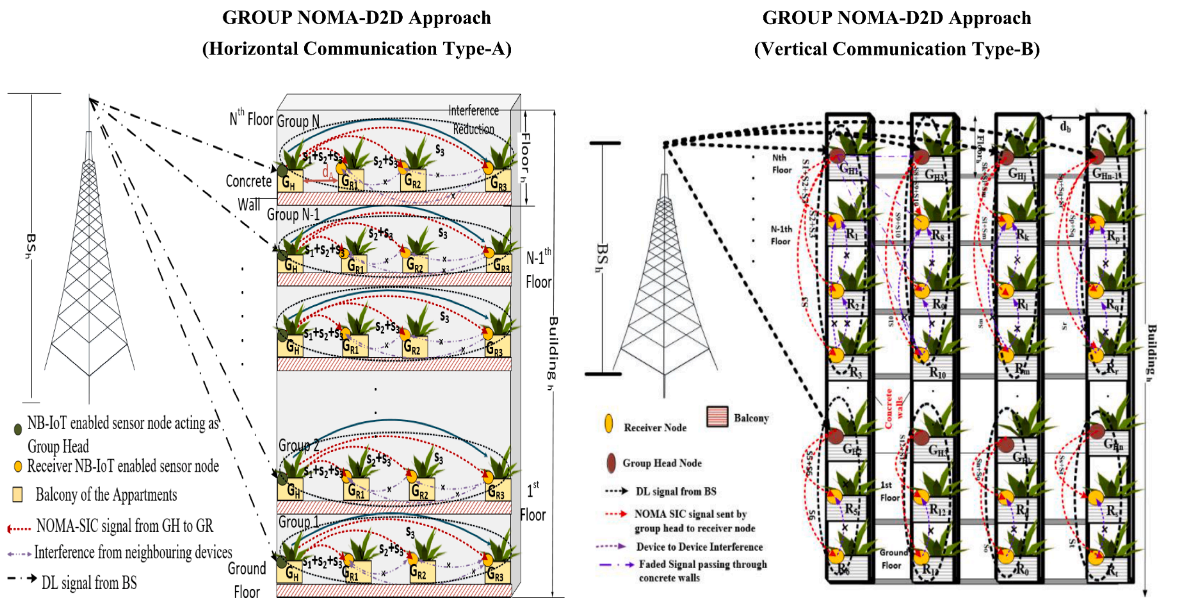


Fig. 3. Resource Allocation for data transmission from D2D transmitter to D2D receiver. [25].



(a) Smart Urban Farming with NOMA-D2D in Multistory Building –Type A (b) Smart Urban Farming with NOMA-D2D in Multistory Building –Type B

Fig. 4. (a) Smart Urban Farming with NOMA-D2D in Multistory Building –Type A (b) Smart Urban Farming with NOMA-D2D in Multistory Building –Type B.



(a) Smart Urban Farming with Group-NOMA-D2D in Multistory Building –Type-A (b) Smart Urban Farming with Group-NOMA-D2D in Multistory Building –Type-B

Fig. 5. (a) Smart Urban Farming with Group-NOMA-D2D in Multistory Building –Type-A (b) Smart Urban Farming with Group-NOMA-D2D in Multistory Building –Type-B.

pairing in a multistory building) as NOMA does superposition coding at the transmitter and successive interference cancellation at the receiver side. The signal received at n^{th} D2D pair d_n^{BS}, on sub-channel, sc_q, considering if D_m^{BS} pairs are sharing the subchannel, sc_q, is expressed as [28]

$$y_{n,q} = \sqrt{\alpha_{n,q}\mathrm{P}^q}\, h_{n,q}\mathfrak{b}_n + \sum_{\substack{j\\ j\neq n}}^{d_m^{BS}} \sqrt{\alpha_{j,q}\mathrm{P}^q}\, h_{n,q}\mathfrak{b}_j + \mathfrak{N}_n \tag{2}$$

Here $\mathfrak{b}_n$ and $\mathfrak{b}_j$ denotes the modulated symbols, $\mathfrak{N}_n \sim C(0,\ \sigma^2)$ is additive white Gaussian noise with zero mean and σ^2 variance. $h_{n,q}$, represents the channel gain from BS to d_n^{BS} the n^{th} D2D pair.

$\alpha_{n,q}\mathrm{P}^q$, denotes the power allocated to the n^{th} D2D pair. Further as D_m^{BS} NB-IoT D2D pairs are allocated on sub-channel q with channel gain order [16]

$$|h_{1,q}|^2 \geq |h_{2,q}|^2 \geq \ldots \geq \left|h_{d_m^{BS},q}\right|^2 \tag{3}$$

Thus to ensure more power allocation to the D2D pair with weak channel conditions in comparison to one with strong channel condition the power coefficients $\alpha_{1,q}, \alpha_{2,q}, \ldots \alpha_{d_m^{BS},q}$ are assigned in the desired manner, such that $\sum_{j=1}^{d_m^{BS}} \alpha_{1,q} = 1$ and it ensures the same.

$$\alpha_{1,q}\mathrm{P}^q < \alpha_{2,q}\mathrm{P}^q < \ldots < \alpha_{d_m^{BS},q}\mathrm{P}^q$$

Henceforth, using SIC decoding order, n^{th} D2D pairs can successfully decode and remove the interference symbol from users $i > n$. However, it can't cancel the interference from $< n$. Therefore the SINR of n^{th}D2D pair on sub-channel sc_q can be simply described as [17]

$$SINR_{n,q} = \frac{\alpha_{n,q}\mathrm{P}^q\ |h_{n,q}|^2}{\sigma^2 + \left(\sum_{i=1}^{n-1}\alpha_{i,q}\right)\mathrm{P}^q|h_{n,q}|^2} \tag{4}$$

This can be understood through Fig. 7, the D2D pair d_1 and d_2 are sharing subchannel q. Where d_1 channel gain is more than d_2. To reduce the cellular interference from BS, the BS transmits the DL superposition

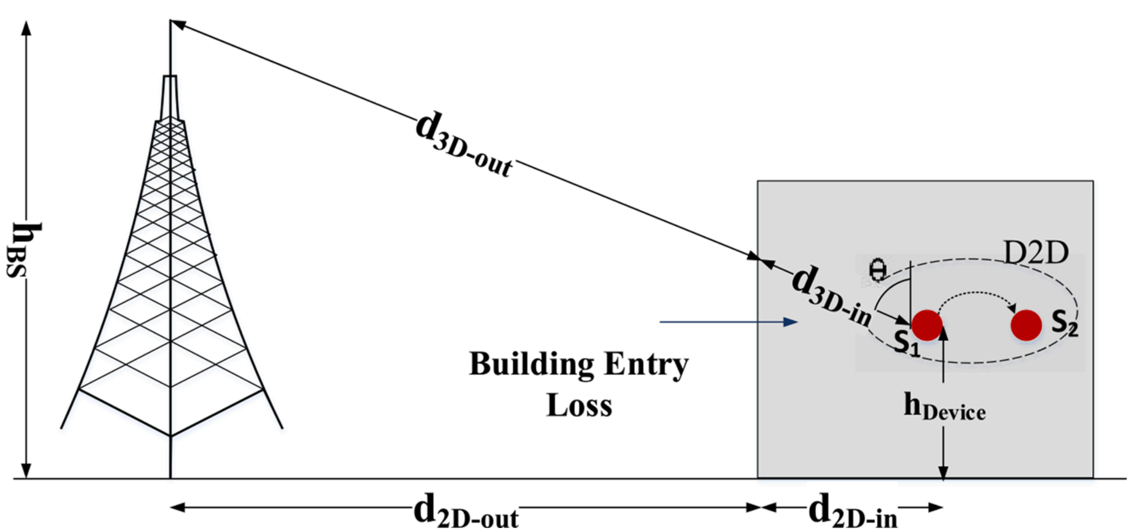


Fig. 6. Distance definition for the device inside the building.

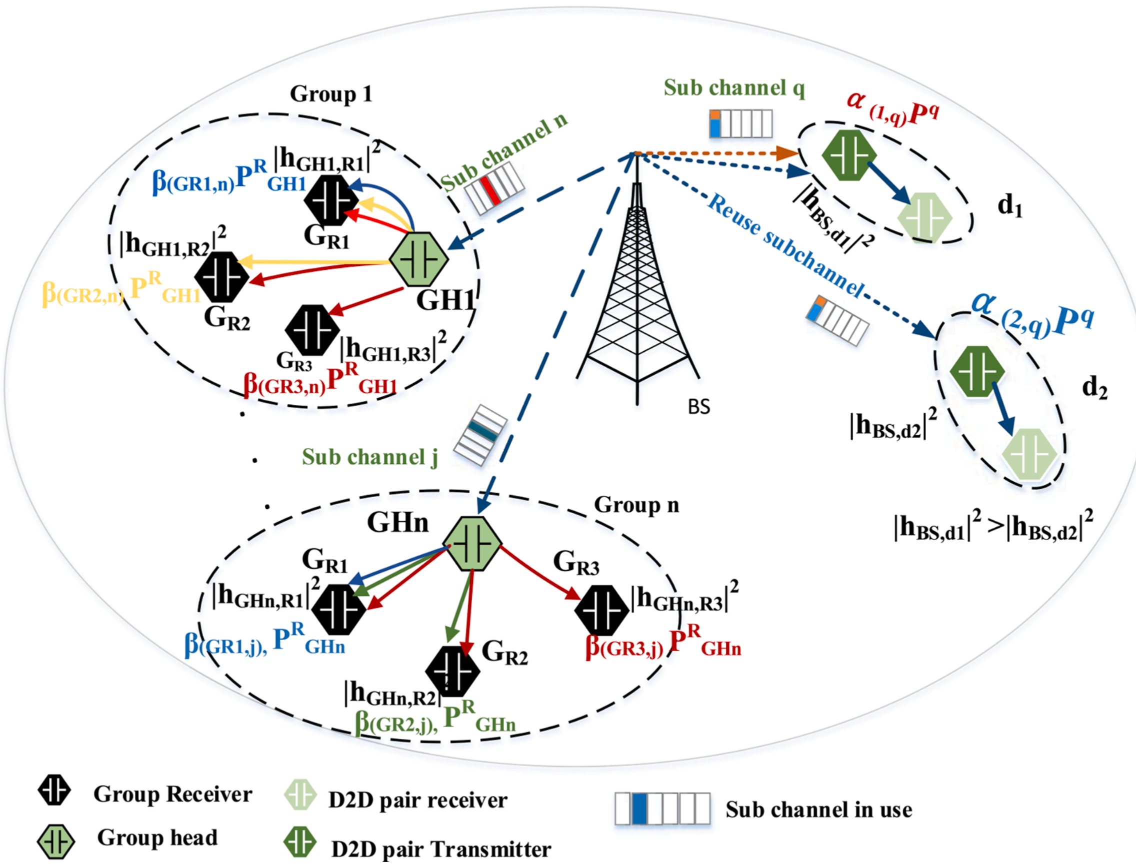


Fig. 7. System description with NOMA SIC.

signals using NOMA principal, *St.* $\alpha_{1,q}P^q < \alpha_{2,q}P^q$. Then d_1 decodes the signal of d_2 and subtracts it from the received signal to detect its signal. Whereas d_2 decodes its signal by treating d_1 with lower power coefficients as noise.

Further assuming transmission bandwidth, to be normalized to 1 Hz, the data rate achieved by n^{th} D2D pair on sub-channel q can be described as

$$\mathscr{R}_{n,q} = \log_2\left(1 + SINR_{n,q}\right) \tag{5}$$

Substituting (4) in eq. (5),

$$\mathscr{R}_{n,q} = \log_2\left(1 + \frac{\alpha_{n,q}P^q\,\left|h_{n,q}\right|^2}{\sigma^2 + \left(\sum_{i=1}^{n-1}\alpha_{i,q}\right)P^q\left|h_{n,q}\right|^2}\right) \tag{6}$$

Total sum rate for D_m^{BS} pair on sub-channel q can be expressed as

$$\mathscr{R}_T^q = \sum_{i=1}^{d_m^{BS}} \mathscr{R}_{i,q} \tag{7}$$

In the case of ***NOMA at the Edge scenario,*** the signal received by the G_R from the G_H is given as

$$y_{G_R} = h_m \sum_{i=1}^{m} \sqrt{\gamma_i P_{GH}^R g_i} + n_m \tag{8}$$

Here P_{GH}^R is the group head transmission power, which is equivalent to the signal received from BS (refer Fig. 7), can be calculated using the equation [29]

$$P_{GH}^R = P^q + \left(H_{BS} - PL_{outdoor} - PL_p + H_{GH}\right) \tag{9}$$

Further as G_m NB-IoT sensor nodes, of $G^i$are allocated on sub-channel q with channel gain order

$$\left|h_{G_{R1}^i,q}\right|^2 \geq \left|h_{G_{R2}^i,q}\right|^2 \geq \ldots \geq \left|h_{G_{Rm}^i,q}\right|^2$$

Here $h_{G_n^i,q}$ represents the channel gain from $G_H^i$to G_{Rn}^i. Similar to the NOMA-D2D approach the Group-NOMA-D2D approach also ensures more power allocation to Group receiver nodes with weak channel conditions in comparison to one with strong channel conditions, the power coefficients $\beta_{G_{R1}^i,q}, \beta_{G_{R2}^i,q}, \ldots \beta_{G_{Rm}^i,q}$ are assigned in the desired manner, such that $\sum_{j=1}^{m}\beta_{j,q} = 1$ and it ensures the same.

$$\beta_{G_{R1}^i,q}P_{GH_i}^R < \beta_{G_{R2}^i,q}P_{GH_i}^R < \ldots < \beta_{G_{Rm}^i,q}P_{GH_i}^R$$

As explained before, henceforth, using SIC decoding order, n^{th} group D2D pairs can successfully decode and remove the interference symbol from users $i < n$.

It can be seen in Fig. 7 the in group 1 the GH1 node is transmitting superposition signals to all the group receiver nodes R1, R2, R3 having channel gain $|h_{GH1,R1}|^2 \geq |h_{GH1,R2}|^2 \geq |h_{GH1,R3}|^2$, with power coefficients allocated inversely proportional to channel conditions, st. $\beta_{R1,n}P_{GH_1}^R < \beta_{R2,n}P_{GH_i}^R < \beta_{R3,n}P_{GH_i}^R$receiver end sensor nodes are decoding and retrieving the desired signal with successive interference cancellations.

Therefore the SINR of n^{th}group D2D pair on sub-channel sc_q can be

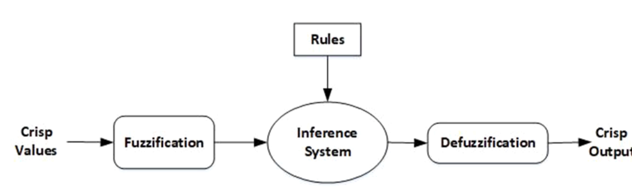


Fig. 8. Fuzzy System Components

simply described as

$$SINR_{n,q}^{G^i} = \frac{\beta_{n,q} P_{GH_i}^{R} \left| h_{G_{Rn}^{i},q} \right|^2}{\sigma^2 + \left(\sum_{j=1}^{n-1} \beta_{j,q} \right) P_{GH_i}^{R} \left| h_{G_{Rn}^{i},q} \right|^2} \tag{10}$$

The data rate achieved by the receiver G_{Rn}^{i} on sub-channel q can be described as

$$R_{Rn,q}^{G^i} = \log_2 \left(1 + \frac{\beta_{n,q} P_{GH_i}^{R} \left| h_{G_n^i,q} \right|^2}{\sigma^2 + \left(\sum_{j=1}^{n-1} \beta_{j,q} \right) P_{GH_i}^{R} \left| h_{G_n^i,q} \right|^2} \right) \tag{11}$$

Total sum rate of Group G^i on sub-channel q can be expressed as

$$\mathscr{R}_T^{q,G^i} = \sum_{i=1}^{G_{Rm}^{i}} R_{Rj,q}^{G^i} \tag{12}$$

3.3. Problem formulation

This section we formulate the optimization problem to maximize the Energy Efficiency (EE) of NB-IoT enabled sensor network deployed in the balconies/faced of multistory buildings for smart farming in urban areas. In a NOMA-NB-IoT enabled D2D wireless sensor network, the energy efficiency is computed as the ratio of the data rate achieved by a pair to the total power consumed by a D2D pair, over a sub-channel, aptly meeting the power constraint.

The total power consumed by the transmitter Group Head i ($\mathscr{P}_{Total}^{GH_i}$) or BS ($\mathscr{P}_{Total}^{BS,q}$) is quantified as a summation of the circuit P_{ckt} and transmission power [28]

$$\mathscr{P}_{Total}^{GH_i} = \sum_{j=1}^{m-1} \beta_{j,Gi} P_{GH_i}^{R} + P_{ckt}{}^{GH} \tag{13a}$$

$$\mathscr{P}_{Total}^{BS,q} = \left(\sum_{i=1}^{m-1} \alpha_{i,q} \right) \mathrm{P}^q + P_{ckt}{}^{BS} \tag{13b}$$

Further Energy efficiency [in bit/joule] is evaluated as the ratio of sum rate to total power consumption, for Group G^i, it is obtained as [30]

$$EE\_GND = \frac{\sum_{i=1}^{m} R_{Rj,q}^{G^i}}{\mathscr{P}_{Total}^{GH_i}} \tag{14a}$$

Here $R_{Rj,q}^{G^i}$denotes the data rate of j th receiver of group i, achieved during DL communication over channel q with group head i, $\mathscr{P}_{Total}^{GH_i}$ denotes the group head i total power, m denotes total number of receivers in a group i

Similarly for D2D pairs on sub-channel q are evaluated as

$$EE\_ND = \frac{\sum_{j=1}^{dm} R_j^{q,BS}}{P_{Total}^{BS,q}} \tag{14b}$$

Here $R_j^{q,BS}$denotes the data rate of j^{th} D2D pair transmitter achieved during DL over subchannel q with BS, $P_{Total}^{BS,q}$ denotes the BS power consumed over channel q, dm denotes the number of D2D pair sharing the sub channel q

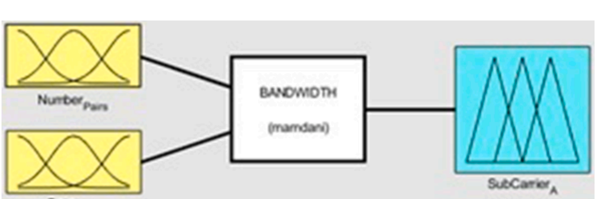


Fig. 9. Fuzzy Logic System for UL resource allocation

3.4. Formulation of the optimization problem

The EE-DL communication in a multistory building with NB-IoT enabled NOMA-D2D-network, the optimization problem can be formulated as

$$\max_j EE\_GND_j^{q,GH_i}, \ \max_j EE_{ND_{dj}}^{q,BS}$$

Subjected to

C1a: $R_{n,q}^{G^i} \geq \mathscr{R}^{TH}$,
C1b: $\mathscr{R}_{n,q} \geq \mathscr{R}^{TH}$
C2a: $\sum_{j=1}^{m-1} \beta_{j,Gi} P_{GH_i}^{R} \leq \ P_{GH_i}$,
C2b: $\sum_{j=1}^{d_m^{BS}} \alpha_{1,q} \ \mathrm{P}^q \leq \ \mathrm{P}^q$
C3a: $\sum_n P_{G_n}^{BS} \leq \sum_{sn} P_{sn}^{BS}$
C3b: $\sum_m P_{D2D}^{BS} \leq \sum_{sn} P_{sn}^{BS}$
C4: $Intf_n^q \leq Intf_n^c$
C5a: $\sum_m \omega < \sum_d \omega, \ \omega = \{SC_1, SC_2..SC_{12}\}$
C5b: $Re_{GH_i}^{Left} > (Re_{GH_i}^{Alct}/2)$

Constraints are specified for both NOMA-based approaches, where constraints related a are for the Group-NOMA-D2D approach and b are for the NOMA-D2D approach.

Constraint C1a and C1b ensures that each NOMA pair achieve the data rate above the threshold data rate $\mathscr{R}^{TH}$ using Group-NOMA-D2D and NOMA-D2D approaches respectively. Constraint C2a ensures that the sum of power allocated to each NB-IoT enabled group receiver sharing the sub-channel shall not exceed the group head total power. Constraint C2b ensures that the sum of power allocated to each NB-IoT D2D sharing the sub-channel shall not exceed the BS total power for that channel. Constraint C3a ensures that total power allocated to n Group Heads may not exceed the BS transmission power utilized for N sensors. Constraint C3b ensures that total power allocated to m D2D pairs may not exceed the BS transmission power utilized for N sensors.

As interference degrades the performance Constraint C4 ensures that using the NOMA-based approach, interference bear by each NB-IoT enabled D2D pair or Group receiver must be reduced. Constraint C5a ensures the total bandwidth allocated for all the NOMA group pairs may not exceed the bandwidth allocated for all the sensor nodes. C5b ensure that Group head will not request for more uplink resource if it's left with more than half of UL resource allocated during the previous iteration.

4. Impact on NB-IoT sensor network interference using NOMA-SIC

In the considered multistory building structures scenario, NB-IoT enabled sensor framework is dense. Thus in this paper pivotal aspects of two power-domain NOMA-based approaches were used to reduce the interference during DL communication. As in a conventional system when BS communicates directly with each sensor node deployed in a multistory building, Interference bear by each node $\mathscr{I}_{conv}^{i}$will be extremely high and evaluated as

$$\mathscr{I}_{conv}^{i} = \underbrace{\sum_{\substack{j=1 \\ i \neq j}}^{l} P_{BS} \left| h_{j,BS} \right|^2}_{\text{Cellularinterference}} + \underbrace{\sum_{\substack{i=1 \\ i \neq j}}^{k} P_d \left| h_{i,j} \right|^2}_{\text{Deviceinterference}} + \sigma_i^2 \tag{15}$$

According to *assumption1*, using direct BS communication the i^{th} device if deployed in the Type-A building, receives interference from the 'k' set of devices on the same floor, whereas in the Type-B building, it receives interference from the 'k' set of the device in the same block. Apart from this cellular interference is also experienced by the i^{th} device

Further, using the conventional D2D approach the number of cellular DL transmissions reduced approximately by half such that $D < l$. Hence the interference $\mathscr{I}^{i}_{d2d}$ received by ith d2d pair, (Here D represents the number of D2D pairs and l number of signals from BS)

$$\mathscr{I}^{i}_{d2d} = \underbrace{\sum_{j\neq i}^{D} P_{BS}\left|h_{j,BS}\right|^2}_{\text{Cellularinterference}} + \underbrace{\sum_{j\neq i}^{D} P_d\left|h_{i,j}\right|^2}_{\text{AdjacentD2Dpairinterference}} + \sigma_i^2, \tag{16}$$
$$\forall\ i,\ s.t\ d_{i,j} < d_{max}$$

In order to further reduce the interference, the *NOMA-D2D* and *Group NOMA* approaches are proposed in this paper.

Since ***NOMA-D2D*** employs SIC at the device side, the interference encountered is fairly canceled in comparison to the conventional D2D approach,

$$\mathscr{I}^{i}_{NOMA} = \underbrace{\left(\sum_{j=1}^{i-1}\alpha_{j,q}\right)P^q_{BS}\left|h_{j,q}\right|^2}_{\text{Cellularinterference (withSIC)}} + \underbrace{\sum_{j}^{d_m^{BS}} P_d\left|h_{i,j}\right|^2}_{\text{AdjacentD2Dpairinterference}} + \sigma_i^2 \tag{17}$$
$$\forall i,\ \left|h_{1,q}\right|^2 \geq \left|h_{2,q}\right|^2 \geq \ldots \geq \left|h_{D_m^{BS},q}\right|^2$$
$$\alpha_{j,q}.P^q_{BS} < P_{BS}$$

Employing the SIC at the receiver for the NOMA-D2D pair, the user with maximum signal strength receives almost negligible interference$(\sum_{j=1}^{i-1}\alpha_{j,q})P^q_{BS}|h_{j,q}|^2 \approx 0$.

This implies

$$\mathscr{I}^{i}_{NOMA} < \mathscr{I}^{i}_{d2d} < \mathscr{I}^{i}_{conv} \tag{18}$$

This reduction in interference results in an improvement in the signal-to-noise ratio, this ultimately will improve the data rate achieved by the D2D pairs, thereby the EE.

In the proposed ***Group-NOMA-D2D*** approach, the number of DL signal transmitted from BS are further reduced in comparison of NOMA-D2D approach. Here instead of BS, the Group head transmits the superimposed signals to group receiver nodes. Thereby the interference received by the m$^{\text{th}}$ group receiver node ($\mathscr{I}^{G^i_m}_{Conv}$) of the i^{th} group without NOMA is given as

$$\mathscr{I}^{G^i_m}_{Conv} = \sum_{\substack{j=1\\ j\neq m}}^{n} \underbrace{\left|h_{G^i_{Rj},q}\right|^2 P^R_{GH_i}}_{\text{AdjacentD2Dpairinterference}} + \sigma_i^2 \tag{19}$$

The interference received by the m$^{\text{th}}$ device $\mathscr{I}^{G^i_m}_{NOMA}$ of the i$^{\text{th}}$ group using the Group-NOMA-D2D approach is given as

$$\mathscr{I}^{G^i_m}_{NOMA} = \underbrace{\left|h_{m,GH_i}\right|^2\left(\sum_{j=1}^{m-1}\beta_{j,Gi}\right)P^R_{GH_i}}_{\text{AdjacentD2DpairinterferenceemployingSIC}} + \sigma_i^2 \tag{20}$$
$$\forall i, \forall j,\ \left|h_{1,GH_i}\right|^2 \geq \left|h_{2,GH_i}\right|^2 \geq \ldots \geq \left|h_{m,GH_i}\right|^2$$

With the transmission of the SIC signal, the sensor device will receive the least interfering signal. Besides this number of the transmitted signal from BS is also reduced. Hence this proves that

$$\mathscr{I}^{G^m_i}_{NOMA} < \mathscr{I}^{G^m_i}_{Conv} \tag{21}$$

5. UL resource allocation to ensure QoE using fuzzy logic

NB-IoT supports both multi-tone and single-tone transmissions in UL. It utilizes a system bandwidth of 180 kHz. However, in order to ensure massive connectivity, the uplink channel designed for NB-IoT is different from LTE two uplink channels designed for NB-IoT are NPRACH & NPUSCH.

NPUSCH carries the uplink data utilizing a bandwidth smaller than one Physical Resource Block (PRB) (i.e. 180 kHz) in terms of subcarriers. It can utilize both 15 kHz and 3.75 kHz numerology for single-tone transmission. Whereas 15 kHz subcarrier spacing for multi-tone transmission.

UE/ device receives the information regarding subcarrier and subframe to be utilized through DCI carried by NPDCCH, during the random access procedure. In this paper to determine resources in terms of the number of subcarriers required to be allocated to each NOMA D2D pair or group receivers for UL communication, *fuzzy logic* is used. The criterion used are no of D2D pairs and their data rate requirements(as shown in Fig. 9).

In the proposed ***NOMA-D2D*** approach the BS listens to the request using Bandwidth fuzzy logic, grant the UL resource. The proposed fuzzy-system reads the value of the Data Rate of D2D pairs. On fuzzifying these input values, fuzzy rules are used. (When no of pairs are less and data

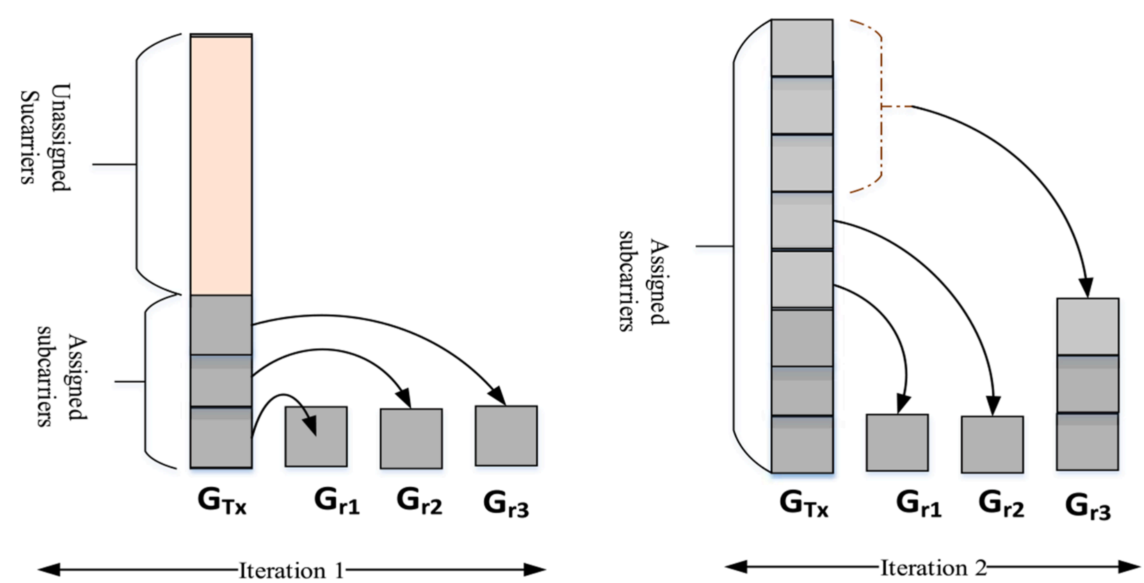


Fig. 10. UL Resource reuse during consecutive iteration (An illustrative example is given in Appendix.).

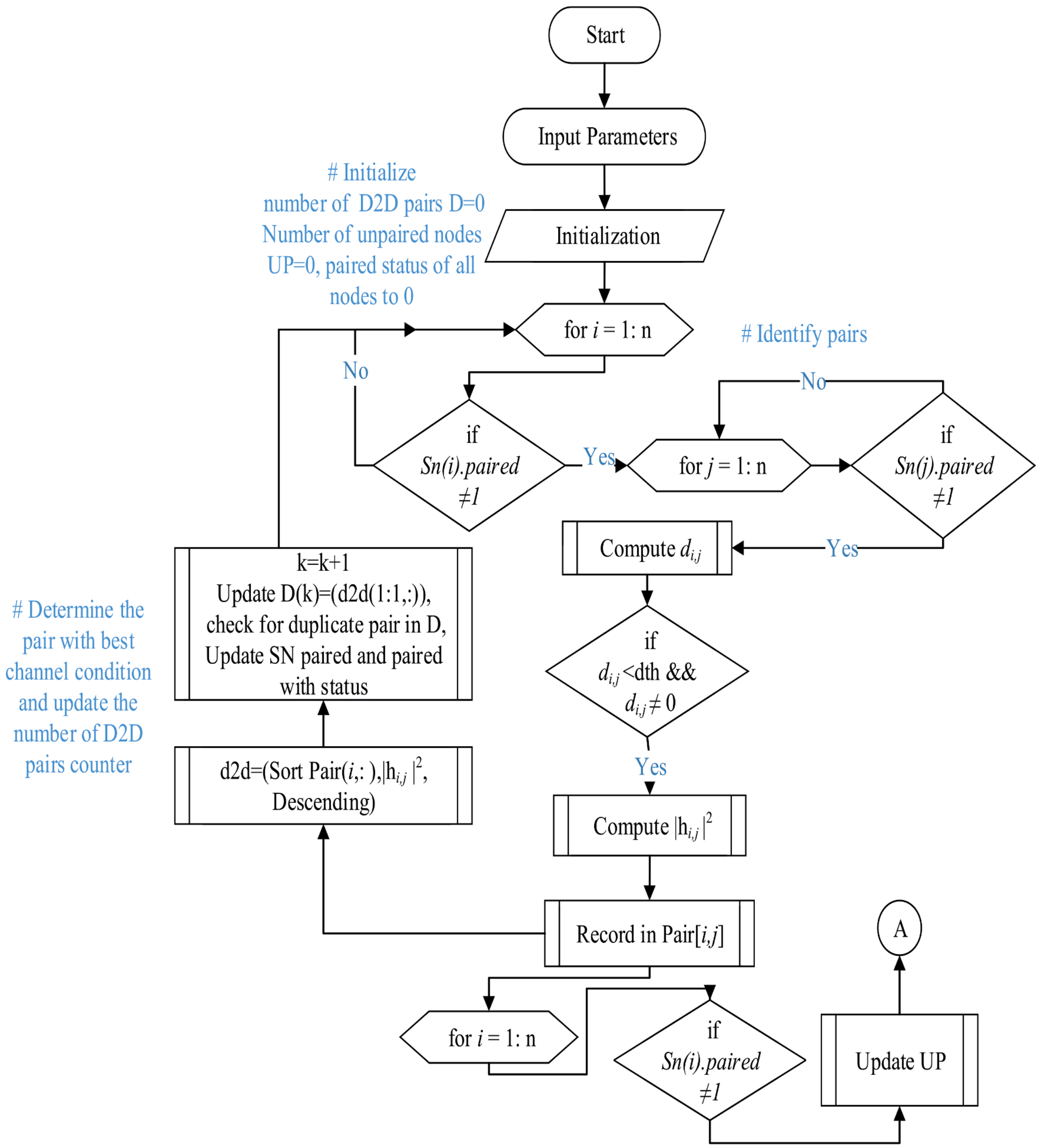


Fig. 11. Flowchart for D2D pair identification.

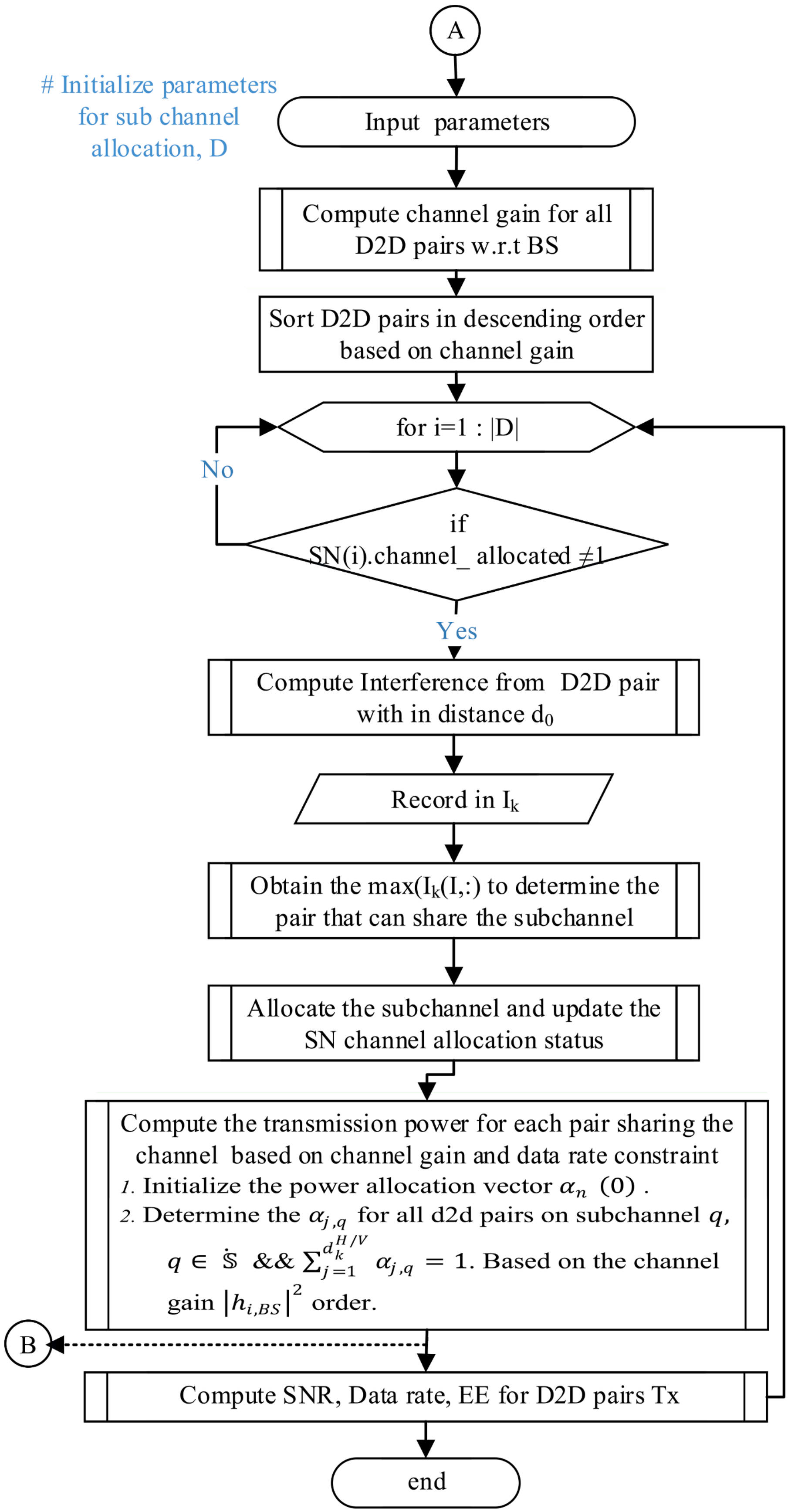


Fig. 12. Interference mitigation using NOMA SIC.

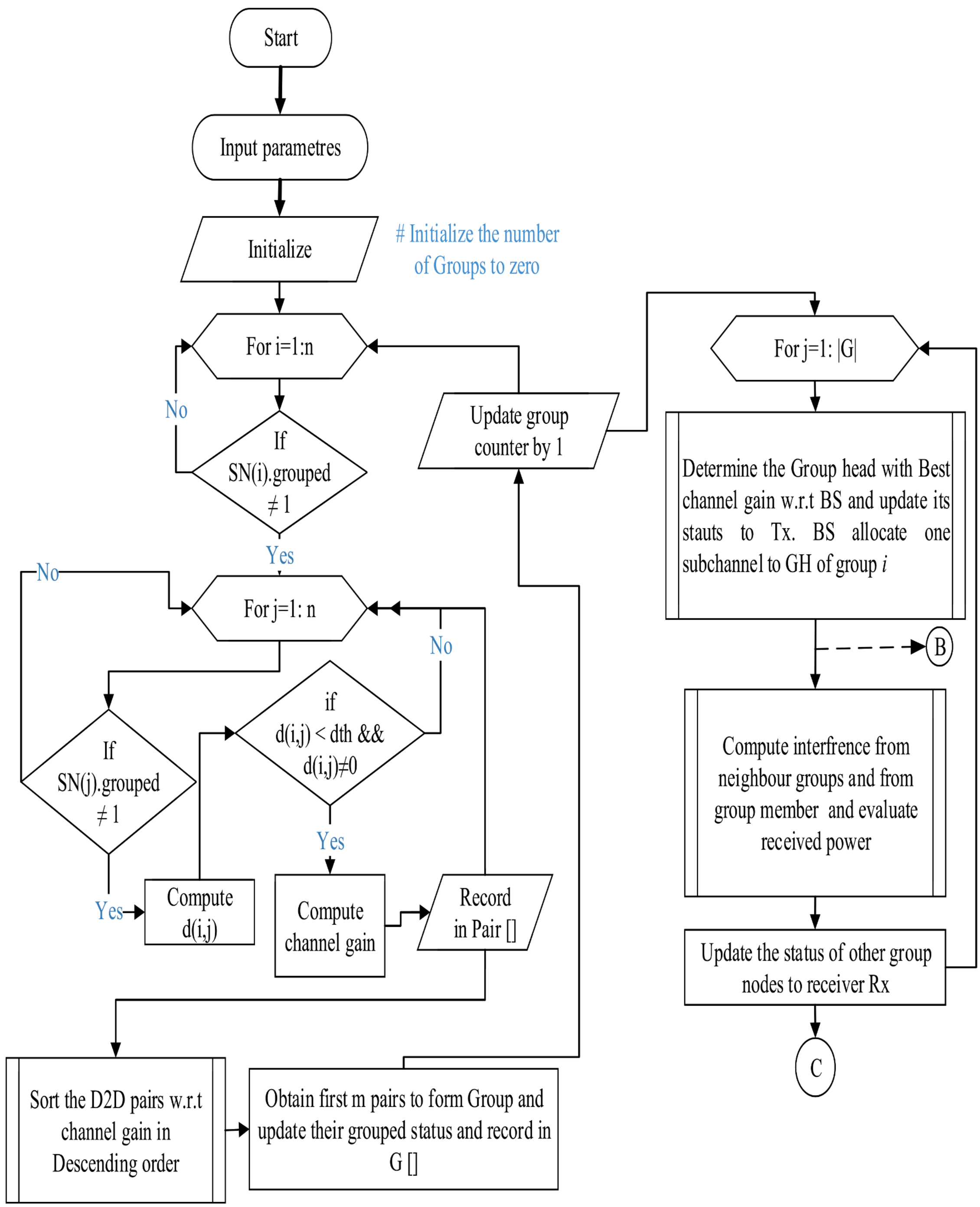


Fig. 13. Flowchart for Group formation and identification of group head and group receiver nodes of all the groups.

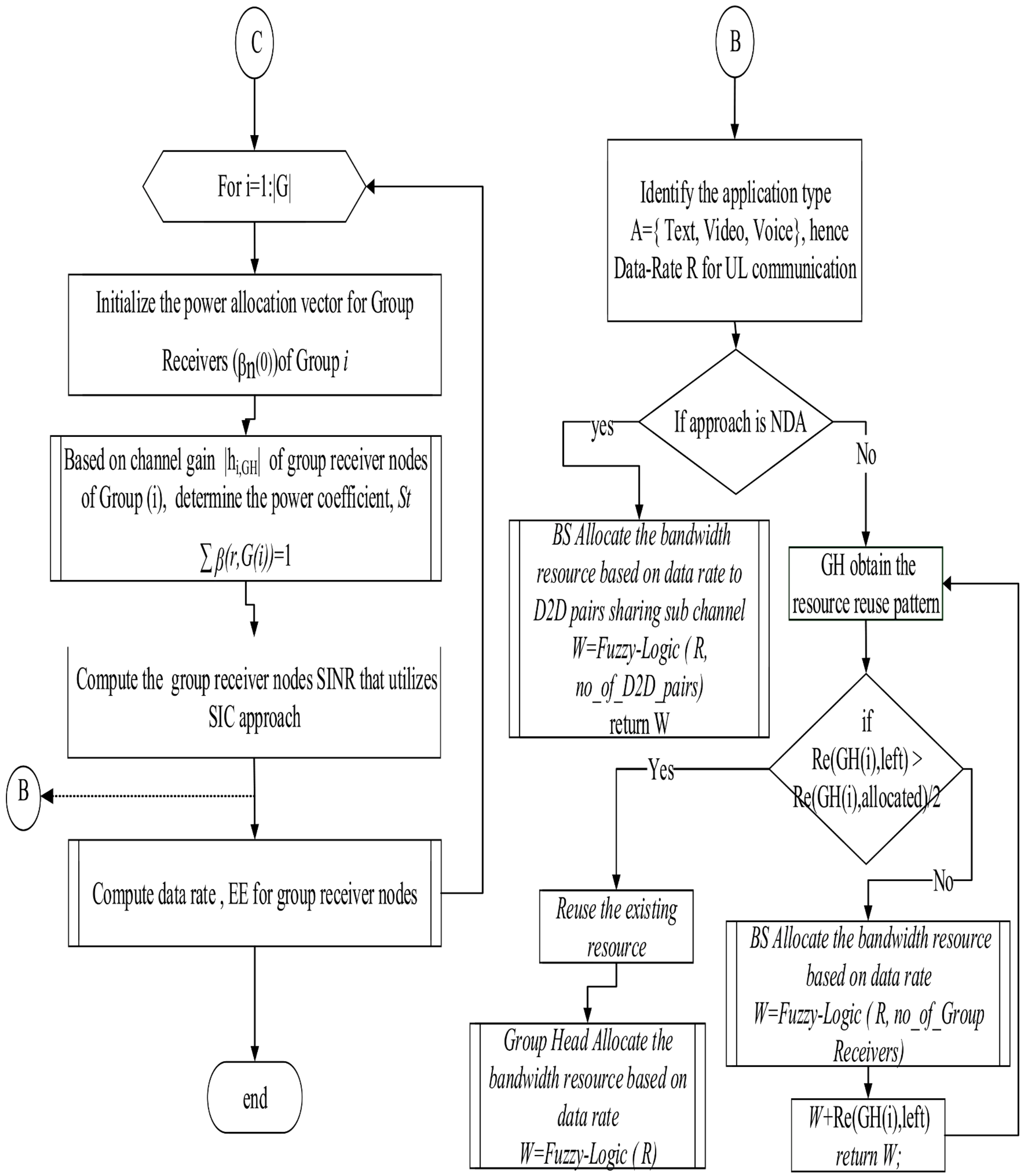


Fig. 14. Group NOMA D2D approach along with resource reutilization.

Table 3
Simulation parameters.

Parameters	Values
Base station radius	500 m
Base Station Antenna height	10 m + building height
Building height	40 m
Base station transmission power	43dBm
Device transmission power	14 dBm
Frequency band *f*	900 MHz
Thermal noise density	-174 dBm/Hz
System bandwidth	180 kHz
Maximum Distance between nodes that form a connected component	20 m
Data rate	20kbps (min) to 250kbps (max)
Log- normal Shadow fading	4dBm
Outdoor Path Loss between the base station and NB-IoT enabled sensors [27]	$P_{r_{LOS}} = 32.4 + 20\log(f) + 20\log(d_{3D-out} + d_{3D-in})$
Path Loss between D2D pair with direct link formation [28]	$P_{D2D} = 148.1 + 40\log_{10}d$
Receiver Noise figure	5dB

rate requirement is less, then the number of subcarriers allocated are less and vice versa).

Thereafter, the crisp value is obtained using de-fuzzification. The crisp value is taken as the weight for the number of subcarriers (The basic fuzzy system components are shown in Fig.8).

Further for the proposed ***Group-NOMA-D2D approach,*** firstly, the group head node will request the BS for complete PRB. Henceforth fuzzification is done for individual Group Receiver node to allocated UL resource among the Group receiver nodes based on application requirements. Since in considered all sensors are considered homogeneous, hence there UL resource requirement. Post allocation, resource left with group head (in terms of subcarrier), is appended for the next iteration.

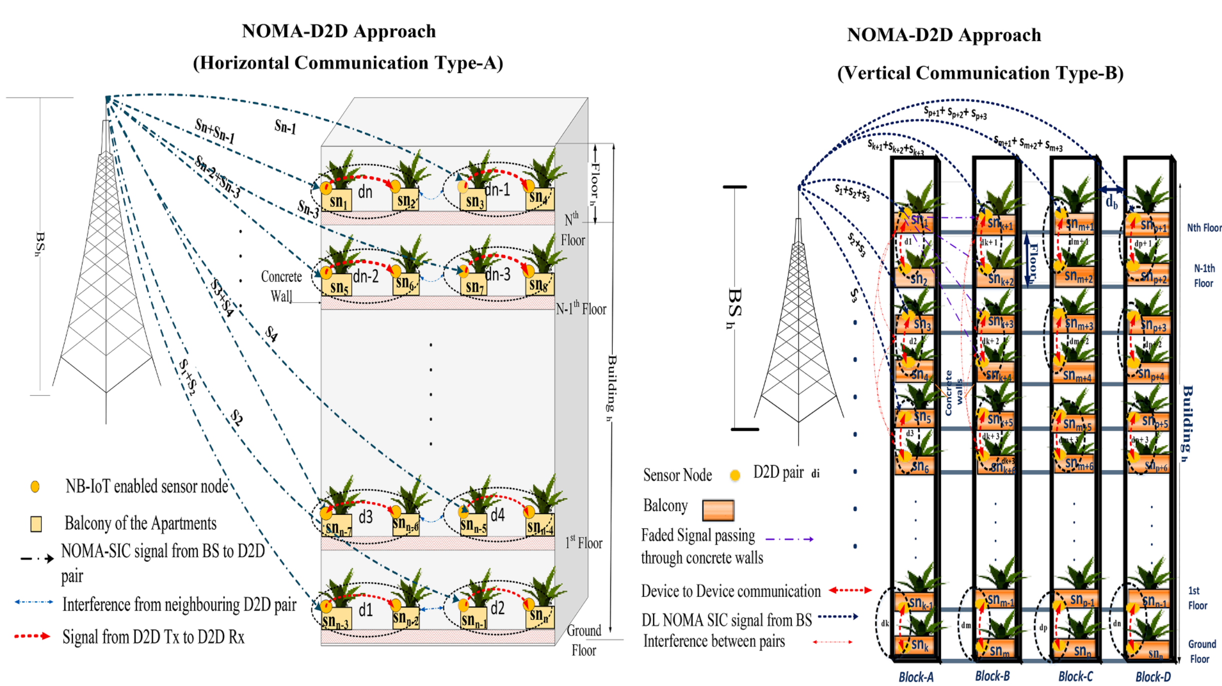
The throughput achieved by individual group receiver nodes on receiving UL grant can be evaluated by eq.22

$$R^{G_i}_{Grj} = \omega \sum_{l \in SC} \left(\log_2 \left(1 + SINR^{l}_{j,q} \right) \right) \tag{22}$$

Here ω is subcarrier, having a bandwidth of 15 *kHz* which is restricted in the bond of $SC \in \{1, 3, 6, 12\}$

Proposition 1. During successive iterations, the i^{th} group head will involve in sharing of the resource block, that hinge collectively on its channel state with the formed group members pairs, and the number of subcarriers left with it s.t it must be at least $> Re^{Alct}_{GH_i}/2$, after sharing in a previous iteration(Fig. 10).

The equation shows that resultant throughput gets improved when the same i^{th} group head is used many times for PRB sharing. Until the i^{th} group head remains active in PRB sharing, the process of aggregation of throughputs continues. Henceforth, the total throughput during different iteration with the fuzzy-based decision of subcarrier allocation of Group is given as [31]



(a) Smart Urban Farming with NOMA-D2D in Multistory Building –Type A (b) Smart Urban Farming with NOMA-D2D in Multistory Building –Type B

Scheme 1. NOMA AT BS for Urban Farming.

$$TR^{i}_{\mathbb{G}} = \sum_{k\epsilon I}\sum_{i\epsilon\mathbb{G}}\sum_{l\in SC}\left(\log_2\left(1+SINR^{l,Gr_i}_{j,q}\right)\right) \quad (23)$$

This ultimately will reduce the number of pings from the device side, which ultimately reduces the BS processing burden. Further, to ensure Quality of Experience (*QoE*) to all the group receiver nodes, MOS is calculated. For j^{th} *group receiver nodes*, during the n^{th} iteration, the MOS is evaluated as [31]

$$MOS^{j}(k) = 5 - \frac{578}{1+\left(\frac{R^{G_i}_{j}(k)+541.1}{45.98}\right)^2} \quad (24)$$

Here $R^{G_i}(k)$ is evaluated as given

$$R^{G_i}(k) = \sum_{\substack{i\in G\\ n\epsilon G_i}} R^{G_i}_{n} \quad (25)$$

Proposition 2. The MOS is, analyzed on a scale between 1 to 5. A value of '5' signifies excellent quality, and '1' denotes the least quality for dynamic cellular communication. However, for static NBIoT enabled sensor nodes MOS values 2 to 3 are sufficient for text and voice communication.

6. Energy efficiency maximization with NOMA approaches

This section represents the pseudo-code for providing useful insight regarding the implementation of the NOMA-D2D and Group-NOMA-D2D approach. Along with pseudo codes Flowcharts are also given in Fig 11, Fig. 12, Fig. 13, and Fig. 14 for better understanding. The pseudo-codes are divided into 5 parts. Pseudocode 1 explains the realization of D2D pair identification in NB-IoT-enabled sensor networks deployed in multistory building balconies. Pair formation between sensor nodes is distance and channel gain dependent. When the distance constraint is fulfilled, a D2D pair is formed and thereafter the possible D2D pairs are sorted based on channel gain, then the node with higher channel gain will finally form the valid D2D pair. The sensor nodes left to be paired will communicate directly with BS. Further pseudo code 2, allocate the subchannel along with the power coefficient to all the NOMA-D2D pairs identified using pseudocode 1 and extracted using pseudocode 2. Finally, the energy efficiency is evaluated. Fig. 11 and Fig 12 describe pseudocode 1 and 2 respectively.

Pseudo Code 1
for the realization of NB-IoT enabled sensor D2D communication

Step1: Input parameters
Cell Radius
Base station : P^{max}_{BS}, P^{q}_{BS}
Building type: A,B, No_of_Floors, No_of_Apartments, dist_BS, dist_appartments
NB-IoT enabled sensor :$\mathscr{S}_i$, $\forall \mathscr{S}_i \in \mathbb{S}$, P_d
Group: $\mathbb{G}$, G_m
Channel: n, σ_0^2
Step2: Initialization
a.Generate the location of the Building with in cell radius.
b.Initialize D2D count to zero
Step3: Check for D2D formation
for i=1:n
if $sn_i.paired \neq 1$
for j=1:n
if $sn_j.paired \neq 1$
Calculate distance between sensor nodes for pair formation
$d_{ij} = \sqrt[2]{((sn_i.x - sn_j.x)^2 + (sn_i.y - sn_j.y)^2)}$
if($d_{ij} < d_{th}$ ***&&*** $d_{ij} \neq 0$***)***
Calculate channel gain $|h_{ij}|^2$
Increment pair counter
Record in Pair[i,j] *matrix* ***/* to store the possible pair with each sensor node*/***
end if
end if

(continued on next column)

Pseudo Code 1 (*continued*)

end for
d2d$_i$ ***= Sort(Pair(i,:)***, $|h_{ij}|^2$***, decending) /* to determine the sensor node having the best channel condition*/***
Increment Counter k by 1
Record it in $D2D(k) = (d2d_i(1:1,:))$;
$sn_{(i)}.paired == 1$
$sn_{(i)}.pairedwith == j$
end if
end for

Pseudo Code 2
for the allocation of Subchannel to the NB-IoT enabled sensor nodes deployed in Multi-story building (using NOMA D2D approach)

Step1: Input parameters
Base station : P^{max}_{BS}, P^{q}_{BS}
Building type: A,B, No_of_Floors, No_of_Apartments, dist_BS, dist_appartments
NB-IoT enabled sensor :$\mathscr{S}_i$, $\forall \mathscr{S}_i \in \mathbb{S}$, P_d
D2D pairs: $d^V_i, d^H_j \in \mathbb{D}$, Pair[]
subchannel: n, σ_0^2, $\dot{\mathbb{S}} = \{sc_1, sc_2, \ldots, sc_M\}$
Step2: Sub-channel Assignment
1. Compute channel gain matrix $|h_{i,BS}|^2$ for all d2d pairs transmitters with BS.
2. Sort D2D pairs based on channel gain :
$|h_{1,BS}|^2 \geq |h_{2,BS}|^2 \geq \ldots \geq |h_{D^H_k,BS}|^2$
3. for i=1 : no of pairs
4. if sn(Id).channel_Identified≠"y"
5. while $j \leq m$
6. Evaluate interference $P_d|h_{ij}|^2$from pairs within the distance $\mathfrak{d}_0$ and record it in I_k for all D2D pairs.
7. Obtain the max $(I_k(i,:))$, to determine the pair that will share the channel and record in→ *Id.* ***/* to reduce the interference and improve the received signal strength using SIC principle*/***
8. Increment the j by 1
9. ***Record it*** *→ sn(i).sharechannel(j)=Id*
10. Update sn(Id).channel_Identified='y'
11. end while
12. ***end for***
13. for i=1: no of pair
14. if$[sn(i).sharechannel(j)].\neq 0$
15. Increment subchannel counter q by 1
16. for u=1: $[sn(i).sharechannel(j)]$
17. Allocate subchannel sc_q ***to the d2d pair*** d^V_i *or* d^H_i,
18. $sn(d^{H/V}_i).SC_{Allocated}='Y'$,
19. end for end if end for
Step 3/* *BS Transmission Power Allocation for D2D pairs, */*
1. Initialize the power allocation vector α_n (0) .
2. Determine the $\alpha_{j,q}$ for all d2d pairs on subchannel q, $q \in \dot{\mathbb{S}}$ && $\sum_{j=1}^{d^{H/V}_k} \alpha_{j,q} = 1$.
Based on the channel gain $|h_{i,BS}|^2$ order.
Step 4:*Evaluate* $\mathscr{R}^q_T$,
Step 5: Compute the EE
Compute the energy efficiency corresponding to all NB-IoT enabled sensor node D2D pairs deployed in multi-story building type A or type B.
EE$_i = f(\alpha_{i,q}, \mathrm{P}^q, \mathscr{R}_{i,q})$.
end for

Further to reduce the interference encountered by neighboring devices/sensor nodes. NOMA at Edge scenario is proposed in this manuscript that utilizes the Group NOMA-D2D approach. Here instead of deciding power coefficients and subchannel assignment at BS. It is proposed that the group head will inform the BS about the number of receiving nodes in the group. Thereafter Group Head will transmit the superimposed channels to the receiving nodes based on channel gain and d max constraint ($d_{j,GH_1} < d_0$)

The steps followed are

Step 1 Using pseudo code 3 the groups are identified based on the distance and channel gain among sensor nodes and updated in the group. Thereafter the node with higher channel gain is will become the group head. These steps are repeated for all the sensor nodes. The maximum number of nodes that can form a group are restricted based on interference. In this study, the number of nodes kept up to 3 as beyond that signal deteriorates badly.

Step 2 Once the group is formed then based on the channel gain the Group head node is elected. Then using the power domain NOMA SIC principle, it will transmit the superimposed signals to the group receiver nodes using pseudocode 4.

Pseudo Code 3
for the realization of NB-IoT enabled sensor Group communication

Step1: Input parameters
Cell Radius,
Base station : P_{BS}^{max}, P_{BS}^{q}
Building type: A, B
NB-IoT enabled sensor :$\mathscr{S}_i$, $\forall \mathscr{S}_i \in \mathbb{S}$, P_d
Group: $\mathbb{G}$, G_m
Channel: n, σ_0^2
Step2: Initialization
1. Generate the location of the Building with in cell radius.
2. Initialize Group count to zero
Step3: Check for Group formation
1. ***for i=1:n***
2. ***if*** $sn_i.grouped == 0$
3. ***for j=1:n***
4. ***if*** $sn_j.grouped == 0$
5. ***Calculate distance between sensor nodes for pair formation***
$d_{ij} = \sqrt[2]{((sn_i.x - sn_j.x)^2 + (sn_i.y - sn_j.y)^2)}$
6. ***if(*** $d_{ij} < d_0$ ***&&*** $d_{ij} \neq 0$***)***
7. ***Calculate channel gain*** $|h_{ij}|^2$
8. ***Increment pair counter***
9. ***Record in*** $pair_i$ ***matrix***
10. ***end if end if***
11. ***end for***
12. g_i = ***Sort(***$pair_i$, $|h_{ij}|^2$, ***decending***)
*/** ***the nodes in its vicinity have higher channel gain will be included*/***
13. ***Obtain first m pairs to form Group***
14. ***Increment Group Counter c by 1***
$G_C = (g_i(1:m, :))$;

(continued on next column)

Pseudo Code 3 (*continued*)

a. ***for k=1: size(***G_c, 1)
$bsn(G_c(k)).grouped == c$. ***end for***
15. ***end for***
for i=1:c /* Step-4 identify the group head of each group*/
for j=1:length(G_i)
Calculate distance between Group sensor node and BS to determine the group Transmitter
$d_{i,j}^{BS} = \sqrt[2]{((sn_i.x - BS.x)^2 + (sn_i.y - BS.y)^2)}$
Calculate channel gain $|h_{i,BS}|^2$ ***for each group node and record in***
$sn(G_i(j))$. $CG_{BS} = |h_{i,j}|^2$
end for
Obtain the node with maximum channel gain with BS
[maxval,maxid]=max(G_i(:, CG_{BS})); $sn(G_i(maxid)).GTx = 1$
Compute $P_{GTx_i}^{R}$ *using eq. 8*
Evaluate Interference from neighboring devices and groups
for j=1: length(G_i***)/* set the status of group receiver nodes*/***
if $sn(G_i(j)).GTx == 0$***; Set*** $sn(G_i(j)).GRx = 1$
end if
end for

Pseudo Code 4
for the realization of the scenario of NB-IoT enabled sensor communication in Multi-story building using NOMA Group D2D approach

Step1: Input parameters
Base station : P_{BS}^{max}
Building type: A, B
NB-IoT enabled sensor :$\mathscr{S}_i$, $\forall \mathscr{S}_i \in \mathbb{S}$, P_d
Group: $\mathbb{G}$, G_m,c
Channel: n, σ_0^2,$\dot{\mathbb{S}} = \{sc_{G1}, sc_{G2}, \ldots, sc_{GM}\}$
Step2: Power Allocation for Groups
a. Initialize the power allocation vector β_n (0).
b. Determine the β_{i,G_i} for all identified Groups Receivers using Pseudocode 3 on subchannel z, $z \in \dot{\mathbb{S}}$
based on the channel gain $|h_{ij}|^2$ of Group Receiver sensor nodes.
c. Compute SINR of receiver nodes
$=F(\beta_{i,z}, P_{GTx_i}^{R}, Intf)$
d. Evaluate throughput for each receiver node
Step 3:*Evaluate* $\mathscr{R}_T^z$, *for each group* $G_m \in \mathbb{G}$

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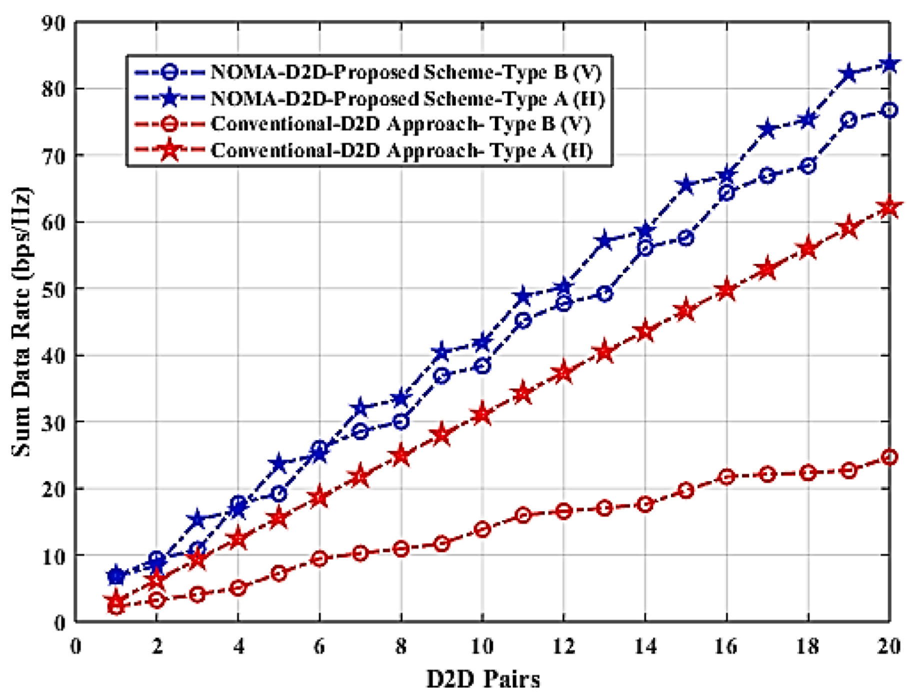


Fig. 15. Sum Data Rate achieved using NOMA-D2D approach and D2D approach for Type A & Type B multi-story building.

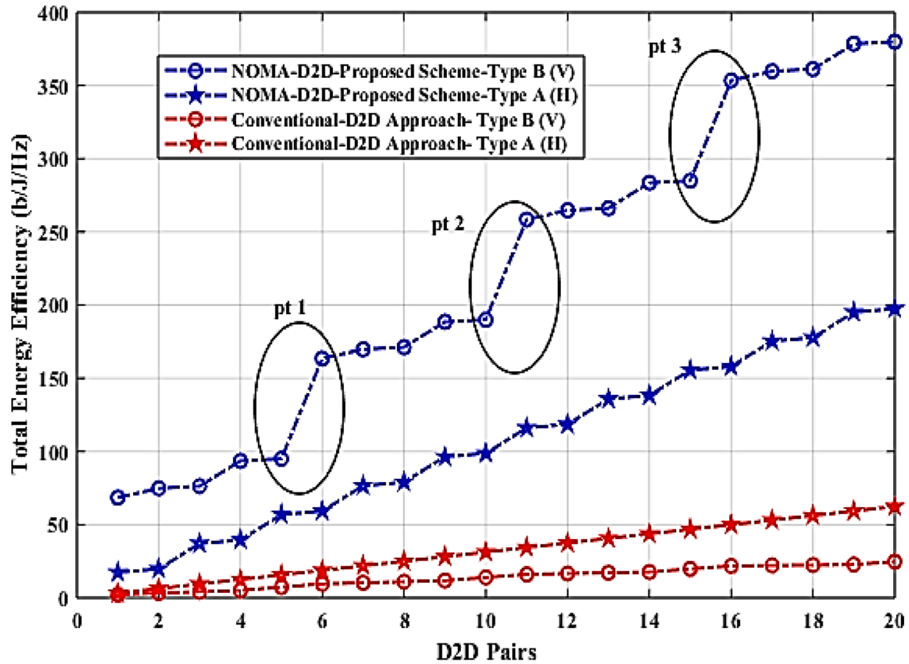


Fig. 16. Comparison of EE achieved using NOMA-D2D and conventional D2D approach on each floor of a multi-story building.

Pseudo Code 4 (*continued*)

Step 4: Compute the TEE
Compute the total energy efficiency corresponding to all NB-IoT enabled sensor node D2D pairs deployed in multi-story building type A or type B.
$TEE_i = f(\beta_{i,z}, P^R_{GTx_i}, \mathscr{R}_{i,z})$.
end for

Apart from making the DL communication more EE, UL resource allocation is also optimized using Fuzzy logic. However, for this two presumptions are taken. Firstly, for this study multitoned subcarrier allocation is considered i.e each subcarrier is 15 kHz. Secondly, in the case of NOMA at BS, i.e. NOMA-D2D approach, a subcarrier allocation decision is taken by BS depending on the type of application, the number of pairs sharing the resource. Whereas is NOMA at Edge, i.e. Group NOMA-D2D approach, to reduce the BS processing complexity, the group head will be allocated a complete physical resource block (i.e. 180 kHz). Then the group head, depending on the type of application, distributes the UL resource adaptively. In addition to this, the resource left with Group Head will be reused during the next iteration. Pseudo-code 5 explains the steps for the UL resource allocation

Pseudo Code 5
for resource allocation to NB-IoT enabled sensor for UL operations during DL communication

Step 1: input parameter
NB-IoT enabled sensor :$\mathscr{S}_i$, $\forall \mathscr{S}_i \in \mathbb{S}$, P_d
D2D pairs: $d_i^V, d_j^H \in \mathbb{D}$
Group: $\mathbb{G}$, G_m,c
Approach: NDA, GNDA
Step2: Resource Allocation
a. Identify the application A={ Text, Video, Voice}, hence Data-Rate R for UL communication
b. If Approach= NDA
Determine the no of D2D pairs sharing the subchannel
W= Fuzzy-Logic (R, no_of_D2D_pairs
Else if Approach= GNDA
Determine the no of Group Receiver nodes sharing the subchannel and store in → GR
1. for j= 1: GR
W= Fuzzy-Logic (R)

(*continued on next column*)

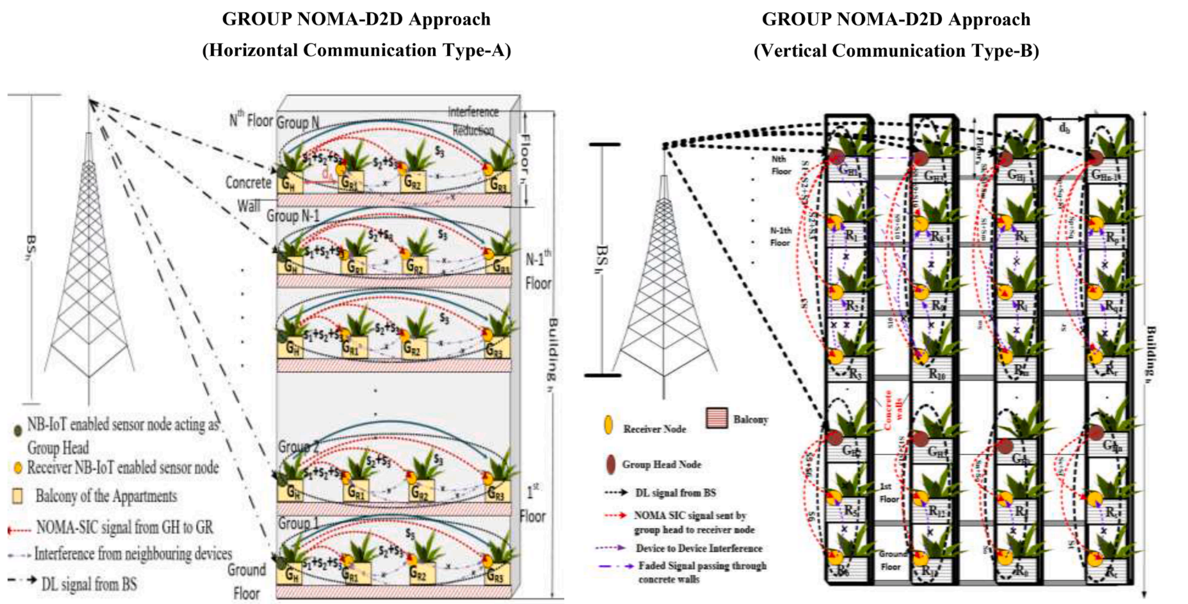
Pseudo Code 5 (*continued*)

end
2. Identify the number of subcarriers left after allocation and no_of_subcarriers allocated
3. Append the leftover subcarriers
4. If $Re^{Left}_{GH_i} > (Re^{Alct}_{GH_i}/2)$, then GH_i will not request for UL resource
5. else
GH_i will not request for UL resource
end if
end if
Step3: Evaluate MOS for each NB-IoT device

7. Result and discussion

This section discusses the performance of the NOMA-based schemes proposed for downlink communication with NBIoT enabled wireless sensor network deployed in a multi-story building. The proposed schemes are categorized into two approaches: NOMA at edge and NOMA at BS. The comparison of the proposed schemes with the conventional *OFDM* scheme is also carried out to show the prospective impact of the proposed approach. In order to analyze the performance, two types of building structures Type-A & Type-B are considered. A Type-A, the building has 10 floors and on each floor, there are 4 apartments (refer Fig. 4a), Type-B building structure has 10 floors and has 4 blocks and each block has 10 apartments (refer Fig. 4b). Loss due to penetration through balcony (L_e, LG_e') [32] are taken as 4 dBm,5 dBm.In the balcony of each apartment, the NB-IoT enables sensors are considered to be deployed for smart automated farming in the balconies. These sensor devices, D2D pairs are formed, if the distance between two sensors i, j i.e. $d_{i,j} < d_0$ and $d_{i,j}$ must be a minimum of all the possible pairs. The simulation parameters are specified in Table 3.

In scheme 1, the NOMA principle is applied at the BS to enhance the EE of the NB-IoT sensor network DL performance. Since, in the conventional D2D approach, BS allocates a dedicated subchannel to each D2D pair and transmits the DL signal with equal transmission power to all D2D pairs. This results in high cellular interference for each D2D pair, as sensor networks deployed are dense. Therefore, to ensure interference-free DL communication, the power-domain NOMA principle is applied at the BS (in scheme-1). In this section, the performance analysis of the NOMA-D2D approach is discussed.



(a) Smart Urban Farming with Group-NOMA-D2D in Multistory Building –Type-A (b) Smart Urban Farming with Group-NOMA-D2D in Multistory Building –Type-B

Scheme 2. NOMA at Edge Device for Urban Farming.

7.1. Analysis of sum rate using NOMA-D2D approach

Fig. 15 illustrates the variation of sum rate with the number of D2D pairs for both considered building structures i.e. Type-A (horizontal communication) & Type-B (vertical communication). It can be observed that the sum-rate for both conventional-D2D and proposed NOMA-D2D approach, increases with the number of D2D pairs. However, in comparison to the conventional D2D approach, the sum rate with the proposed NOMA-D2D approach was found to be improved by 0.3 to 1.19 and 1.6 to 2.5 times for Type-A and Type-B building structures respectively. This higher sum rate is achieved due to curtailed interference (attained using successive interference cancellation) among D2D pairs communicating on the same DL channel with BS.

It was also found, improvement in sum rate is more for Type-B compared to Type-A building structure using the NOMA-D2D approach. Since in Type-A, the maximum number of D2D pairs that have shared the one subchannel are less than Type-B, (*refer Fig. 4a, Ground Floor it can be seen that at max 2 D2D pairs* i.e. *1, 2 have shared one subchannel, whereas in Type-B Fig. 4b, Block –A, 3 D2D pairs* i.e. *1, 2, and 3 shared one subchannel, and within same block 2 more D2D pair* i.e. *4 and 5 have shared another one subchannel*). Thus due to more adjacent D2D pair interference cancellation with NOMA-SIC, SINR of D2D pairs in Type B building structures was found to be improved more than Type-A.

Conclusively, the number of D2D pairs that share the channel significantly impacts the sum rate.

7.2. Analysis of EE using NOMA-D2D approach

The variation of EE achieved for NB-IoT enabled sensor network deployed in two building structures i.e. Type-A & B with respect to the number of D2D pairs is depicted by Fig. 16. It was observed that with the proposed NOMA-D2D approach the EE of NB-IoT enabled NOMA-D2D pairs improved remarkably (by 0.5 to 1.7 times and 7 to 11 times) for Type-A & Type-B building scenario than conventional-D2D approach. This is due to curtailed interference and optimized BS power utilization.

Further, it can be observed, the EE improvement with the NOMA-D2D approach is relatively linear for Type-A building, whereas it highly varying for Type-B building. The sudden rise in EE for Type-B building D2D pair, observed *at pt 1 (*i.e. *from pair 5 to 6), pt. 2 (*i.e. *from pair 10–11), and pt. 3(*i.e. *from pair 15 to 16)* is due to improvement in channel gain of D2D pair 6,11 and 16 w.r.t BS (being at top Floor) and optimal power utilization.

In addition to this, it can also be seen that the trend of EE (for type A & B building scenario) for both the conventional D2D and proposed NOMA-D2D approach was not found to be similar to that of the sum rate of D2D pairs. Since EE is evaluated by taking the ratio of achieved data rate to the utilized total transmission power. Thereby in Type-A, the BS transmission power for each subchannel $q,(P^q)$ is distributed among 2 intra-floor D2D pairs that have shared the subchannel (on each floor with different power coefficients). Whereas in Type B building structure, it is distributed among 3[1] inter-floor D2D pairs within each Block.

In scheme 2, the NOMA principle is applied at the edge. As using the NOMA principle at BS, cellular[2] interference was curtailed considerably. However, to further reduce the device interference to a significant level, the Group NOMA-D2D approach is used (i.e. instead of BS, the Group head will use NOMA principal and transmit the superimposed signals to group receiver nodes). Besides this, the signal transmitted from BS also reduces, and so as the number of subchannels utilization, thereby allowing more device to be connected. The performance analysis of the GNDA approach is discussed in subsequent sub-sections.

7.3. Analysis of sum rate using group-NOMA-D2D approach

The variation of sum rate with a number of groups of NB-IoT enabled sensor nodes formed in Type-A & Type-B building structures is shown in Fig. 17 (a) and Fig. 17 (b) respectively. Firstly, to compare the results attained for the Type-A building with the proposed Group-NOMA-D2D to that of the proposed NOMA-D2D approach, a floor-wise comparison is done. Since the number of D2D pairs formed using both above-stated approaches are not the same. (*The total number of groups formed in the Type-A building are 10, one on each floor, with 3 Group receivers and 1 Group Head, in each group. Whereas the total number of D2D pairs formed*

[1] In type B building structure, 5 D2D pairs are formed of sensor deployed in one block. Using NOMA- D2D approach it was found that in block-A, pair 1, 2, 3 shared one subchannel and 4 and 5 shared one subchannel.

[2] Cellular here refers to Interference due to DL signals from BS for neighbour D2D pairs.

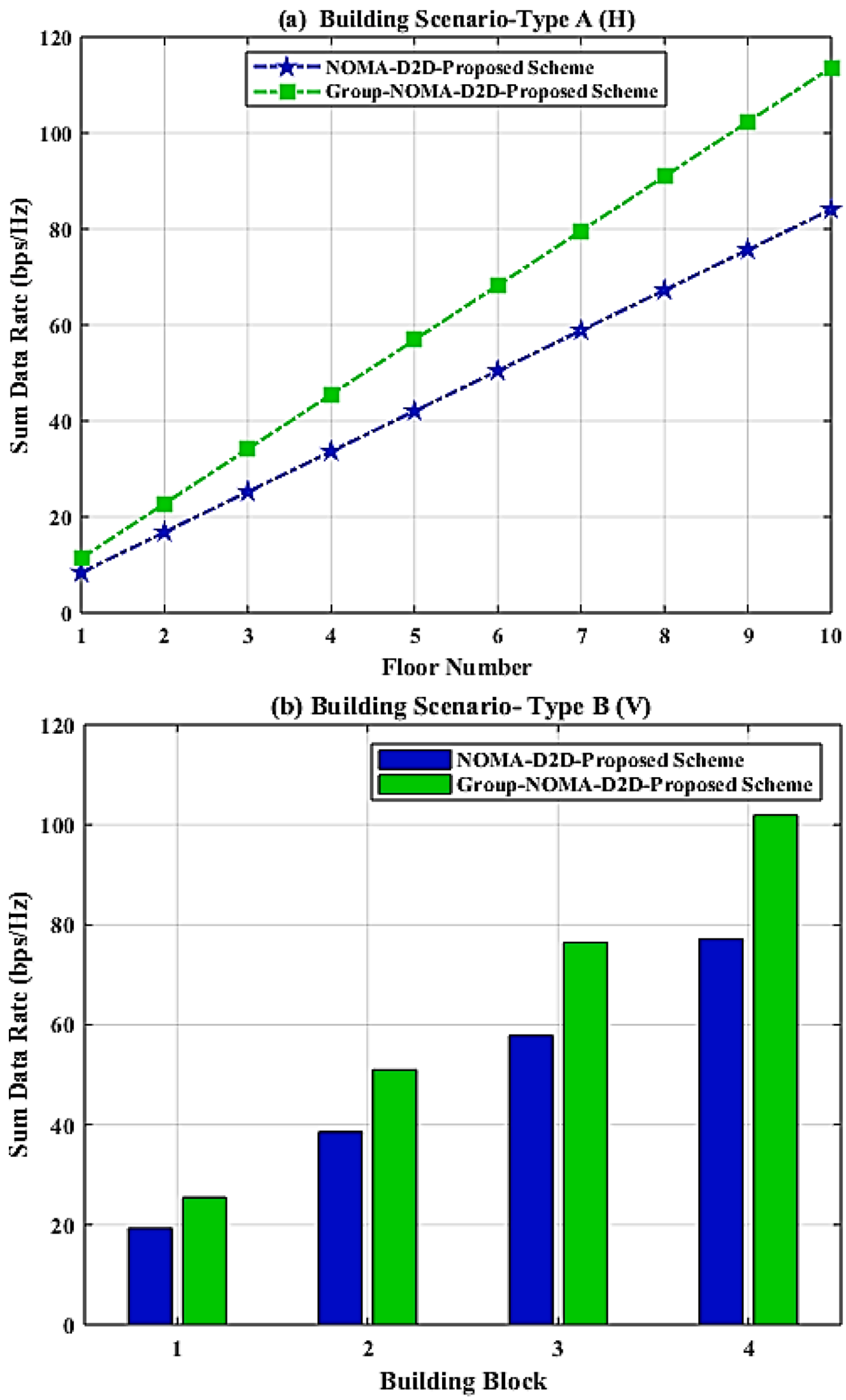


Fig. 17. (a) Comparison of Sum rate achieved using NOMA-D2D and Group NOMA-D2D approach on each floor of Type-A (H) [3] multi-story building. (b) Comparison of sum rate achieved using NOMA-D2D and Group NOMA-D2D approach at each block of Type-B(V)[4] multi-story building.

using the NOMA-D2D approach are 20, 2 on each floor.) Further, to compare the results of the proposed Group-NOMA-D2D and NOMA-D2D approach for Type-B building, Block wise comparison is done. This also due to an unequal number of D2D pairs formed using both approaches. *(The total numbers of Groups formed in Type B are 12, where 3 groups are formed in each block. Group1 formed in Block-A has 3 receivers and 1 Group head node. Group-2 and Group-3 have 2 receiver nodes and one Group head node. Whereas the number of D2D pairs formed are 5 in each block.*)

It can be seen there is a gradual increase in sum rate with an increase in the number of groups for both Type-A & Type-B. In a comparison of NOMA-D2D, the Group NOMA-D2D approach further improved the sum rate by 35% for type-A and 32.1% for type-B building scenarios. This improvement is due to improved channel gain between the transmitter, (i.e. Group Head) and receiver nodes and also reduced cellular and

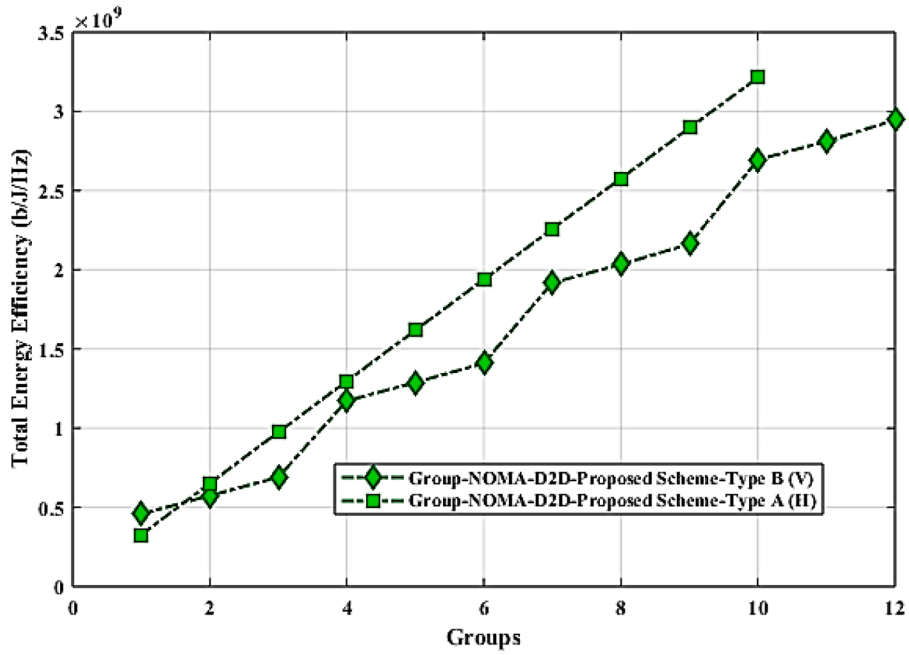


Fig. 18. Variation in EE with the number of groups achieved using Group NOMA-D2D approach at Type-A and Type-B multi-story building.

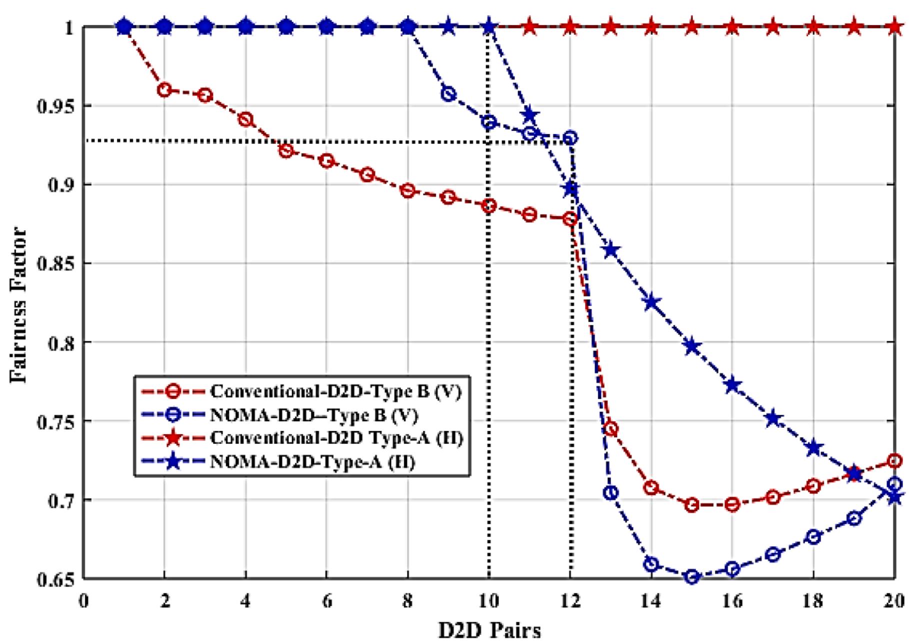


Fig. 19. Comparison of Fairness Factor achieved using NOMA-D2D and conventional D2D approach at Type-A and Type-B multi-story building.

device interference.

This signifies that NOMA at edge greatly impacts the performance of the NB-IoT sensor network in comparison to NOMA at BS.

[3] H= Horizontal Communication with in same floor among NB-IoT enabled sensor devices. (refer Fig. 4a& 5a).

[4] V=Vertical Communication among NB-IoT sensor nodes deployed on different Floors (refer Fig. 4b& 5b).

7.4. Analysis of EE using group NOMA-D2D approach

Fig. 18. depicts that the EE increases with a growing number of Groups. The number groups formed are 12 for Type-B and 10 for Type-A. With the Group-NOMA-D2D approach, each group receiver sensor node receive the DL signal with considerably reduced transmission power,$P^R_{GH_i}$ that ultimately impact the EE of all group receiver nodes (As EE is evaluated by the ratio of throughput by transmission power). Thus in comparison to the NOMA-D2D approach Group-NOMA-D2D approach significantly improves the EE of the NB-IoT enabled sensor network

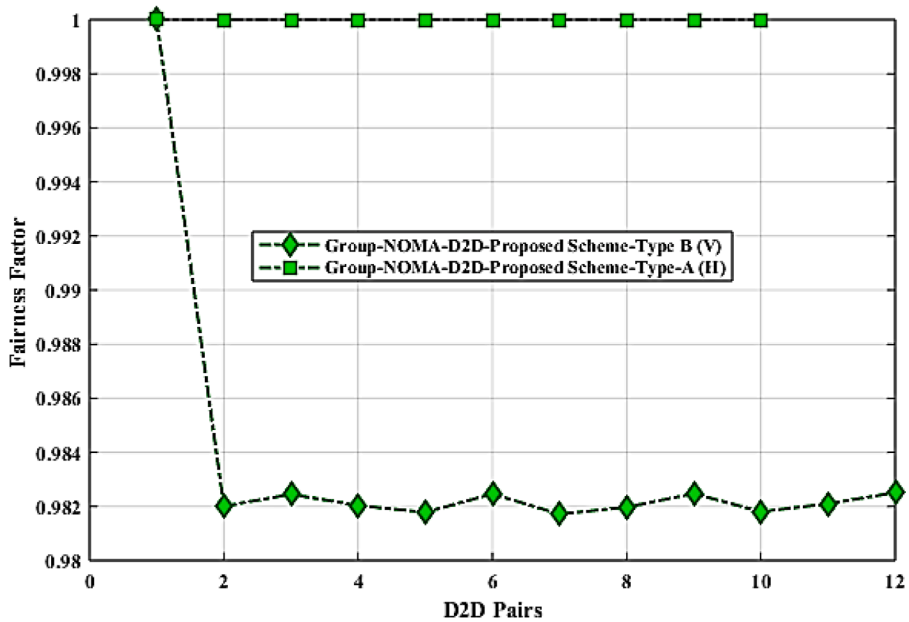


Fig. 20. Fairness Factor achieved using Group NOMA-D2D approach at Type-A and Type-B multi-story building.

deployed in a multistory building.

7.5. Fairness factor analysis

The performance of the conventional D2D, NOMA-D2D, and Group-NOMA approaches has also been evaluated in terms of fairness factor.

For this evaluation, Jains Fairness is used here given by, $FF_{conv/NDA} = \frac{\left(\sum_{j=1}^{d_m^{BS}} \mathscr{R}_{n,q}\right)^2}{D_m * \sum_{j=1}^{d_m^{BS}} (\mathscr{R}_{n,q})^2}$. Based on the evaluated results Fig. 19 depicts the variation of fairness factor with the number of D2D pairs. It can be observed that with the NOMA-D2D approach, 10 to 12 NB-IoT enabled D2D pair achieves higher or equivalent fairness factor to conventional D2D pairs for both (Type-A & Type-B) building structure. This is due to the higher transmission power utilization in the conventional D2D approach for all D2D pairs in comparison to the proposed NOMA-D2D approach. With the conventional D2D approach, BS transmission power is equally distributed among 20 D2D pairs using proportional distribution. Whereas in the NOMA-D2D approach only half of the total BS transmission power is utilized and subchannels to cater to the same D2D pairs.

Thus it can be inferred that although the fairness factor is decreased, yet EE is improved, and complexity in terms of power and subchannel utilization is also reduced.

To further enhance the fairness factor of the NB-IoT sensor network deployed in the multistory building Type-A & B, the Group-NOMA-D2D approach is used. Here it can be seen in Fig. 20 for type-A, the FF achieved is equivalent to the conventional D2D approach and better than the NOMA-D2D approach, but in more EE way (refer Fig. 18) whereas for Type-B Group-NOMA-D2D approach outperformed the NOMA-D2D and conventional D2D approach.

7.6. Impact of bandwidth optimization using fuzzy logic for UL communication

Fig. 21 shows the ruleset used when the number of pairs are 1, 2, and 3 respectively with a fixed small data rate requirement of 38.4 kbps. As already specified that NB- IoT abides by multitoned resource allocation for UL communication in terms of subcarriers {1, 3, 6, 12}. The proposed fuzzy logic also adheres to the same minimum multitoned subcarrier allocation. Hence it can be seen in Fig. 21 (a) when the number of D2D pairs is 1, then the UL grant is $\lfloor 1.39 \rfloor . \sim= 1$, 1*15 kHz. However, when the number of pairs increased to 2, for the same data rate requirement then the UL grant is $\lfloor 4.21 \rfloor . \sim= 4$ (Fig. 21(b))but abiding by law it can be 3 only 3*15=45 kHz. Similarly, when the number of pairs further increased to 3, the uplink grant is not changed and kept at 45 kHz (Fig. 21(c)).

Post evaluating the UL grant for minimum data rate requirement, the impact of change in data rate requirement, and the number of D2D pairs are evaluated and represented in Fig. 22. It has been observed that abiding by the law of NB-IoT UL resource allocation, with the increase in data rate requirement the subcarrier requirement also increases. *(Here the number of pairs considered are 3 only because beyond that interference increases significantly and hence the received signal strength decreases significantly.)*

Further, to investigate the impact of UL resource grant optimization using Fuzzy Logic, *QoE* of the sensor device in terms of the *mean opinion square* values have been analysed and presented in Table 4 and Table 5 for Type-A respectively.

In this considered study the sensor deployed are homogeneous and considered to transmit the same parameter of individual green balconies. Evaluating the MOS it was found that optimizing the UL grant using fuzzy logic, *Group-NOMA-D2D* obtained higher MOS than *NOMA-D2D* approach for each floor in the case of Type-A scenario. Similarly, MOS obtained for the Type-B scenario was also found to be higher using the Group- NOMA-D2D approach in comparison to the NOMA-D2D approach. The MOS achieved is improved by 2–14 % using the Group-NOMA-D2D approach.

8. Conclusion

Urban structures are potentially being leveraged to ensure local urban food security. Currently, IoT-based solutions are used to assure food quality and improve productivity However, literature related to the energy-efficient IoT-based urban farming communication solutions available are very few. Thereby in this study, two EE NOMA-based approaches (i.e. NOMA-at–BS & NOMA-at-Edge) have been proposed for NB-IoT enabled sensor networks deployed in urban structures for

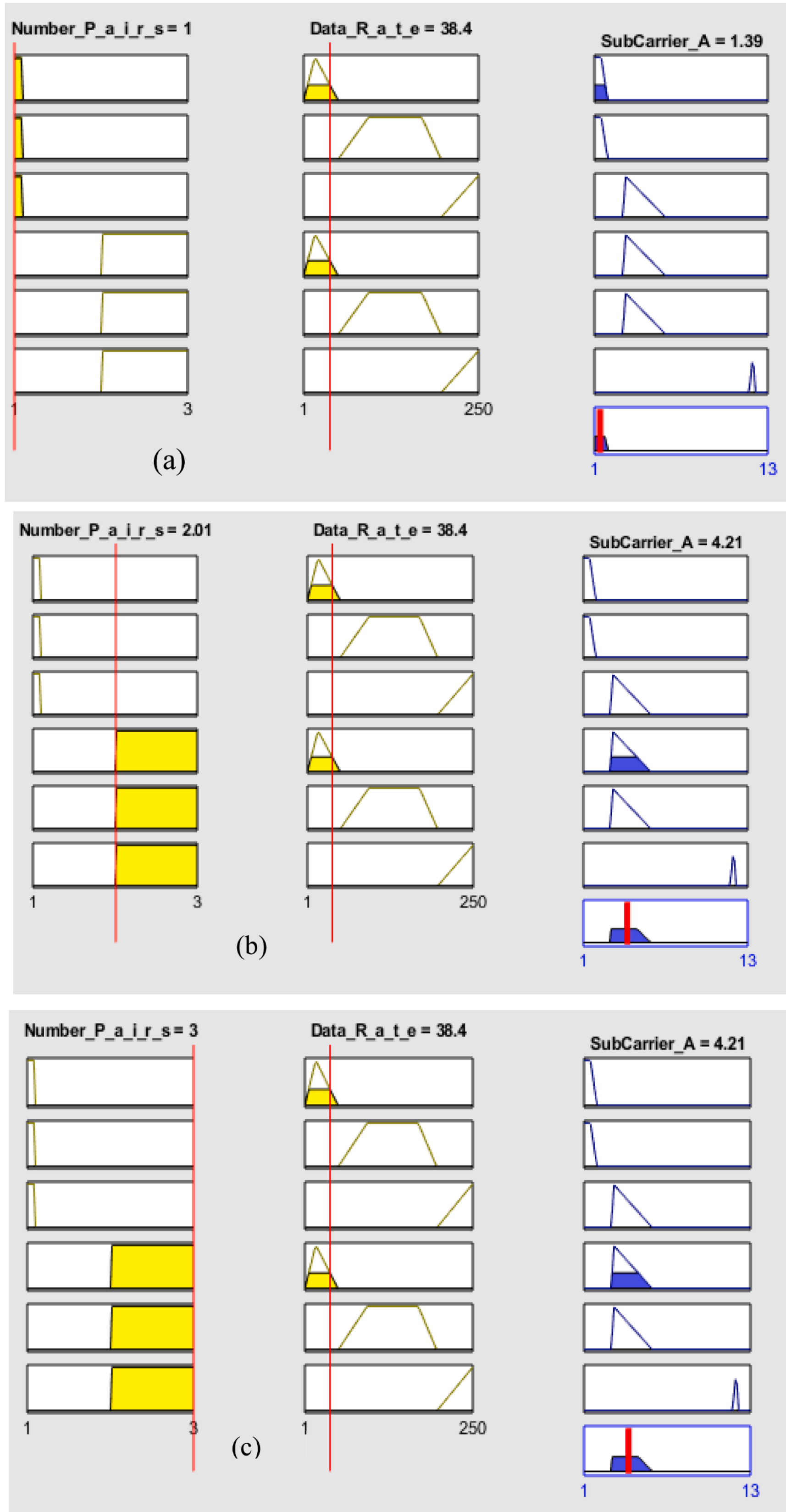


Fig. 21. Subcarrier allocation for (a) 1 D2D pair (b) 2 D2D pairs and (c) 3 D2D pairs for minimum data rate (38.4 kbps) using proposed bandwidth Fuzzy Logic.

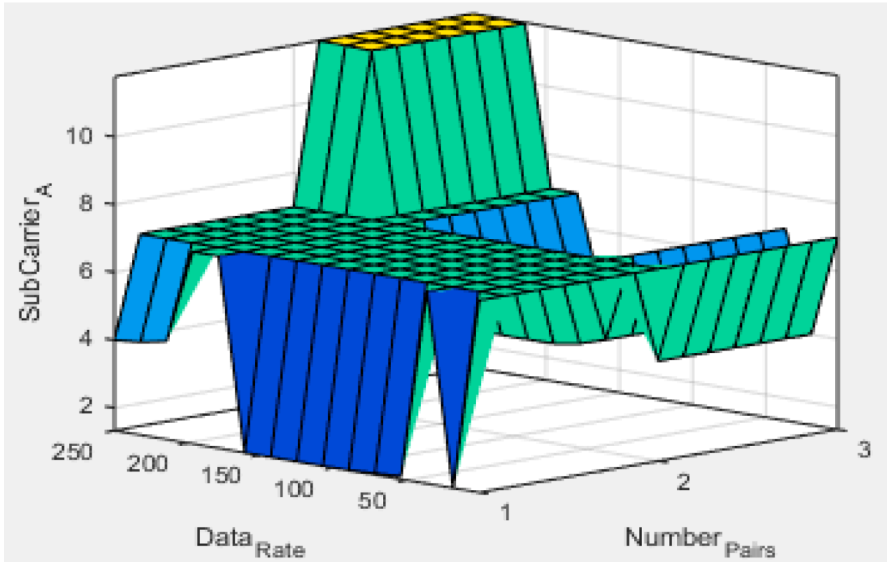


Fig. 22. Subcarrier allocation with varying number of D2D pairs sharing subchannel and Data Rate using proposed bandwidth Fuzzy Logic.

Table 4
MOS values for group-NOMA-D2D (Type-A (H)).

Resource Allocation	MOS NOMA-D2D	Total UL Resource allocated for max D2D pair=2	MOSGroup NOMA D2D	No_of PRB used for max D2D pair=3
15kHz	2.19	30kHz	2.5	1, left with 75% of resource for resuse
45kHz	3.45	90kHz	3.9	1, left with 25% of resource for reuse
90 kHz	4.19	180kHz	4.5	2, left with 50% of resource for reuse
180kHz	4.6	360kHz	4.8	3

Table 5
MOS values for group-NOMA-D2D (Type-B (V)).

Resource Allocation	MOS NOMA-D2D	Total UL Resource allocated for max D2D pair=3	MOSGroup NOMA D2D	No_of PRB used for max D2D pair=3
15kHz	3.15	45kHz	3.3	1, left with 75% of resource for resuse
45kHz	4.3	135kHz	4.4	1, left with 25% of resource for reuse
90 kHz	4.7	270kHz	4.7	2, left with 50% of resource for reuse
180kHz	4.8	540kHz	4.9	3

farming. Through simulation results, it has been observed that NOMA-at Edge assures the green communication more promisingly than NOMA-at-BS. Because the Group-NOMA-D2D approach, has not only reduced the number of signals from BS, but it has also significantly reduced the device interference, in comparison to the NOMA-D2D approach. The simulation results also revealed that the proposed NOMA-at-edge (Group-NOMA-D2D) approach proves to be more EE scheme for multi-story urban farming structures.

- NOMA-D2D improved the sum rate of Type-A and Type-B building structures by approximately 0.34 to 1.19 and 1.6 to 2.5 times in comparison to the conventional D2D approach. Further, In comparison to NOMA-D2D, Group-NOMA-D2D improved the sum rate by 35% and 32% for Type-A and Type-B respectively.
- The Group-NOMA-D2D approach significantly improved the total EE of the NB-IoT network deployed in urban structure, in comparison to the conventional D2D approach and NOMA-D2D approach.
- NB-IoT sensor network deployed in considered urban structures achieved a good fairness factor in the range of 1–0.98 and 1–0.65 using the Group-NOMA-D2D & NOMA-D2D approach respectively.
- The proposed NOMA-approached reduced the number of sub-channels utilization, hence improves connectivity.
- In addition to this, the UL resource grant is also optimized using the proposed Fuzzy Logic approach for NB-IoT enabled sensors network. Thereby improved the QoE evaluated in terms of MOS by 2–14%.

Declaration of Competing Interest

Here I declare that there is no conflict of interest of this manuscript in any form.

Appendix

Real-Time Building Structure used for evaluation

Fig. (a) Building Structure Type-A, (Residential building at Shri Mata Vaishno Devi Narayana Hospital, Katra)

Fig. (b) Building Structure Type-B, (Residential building at Shri Mata Vaishno Devi University, Katra)

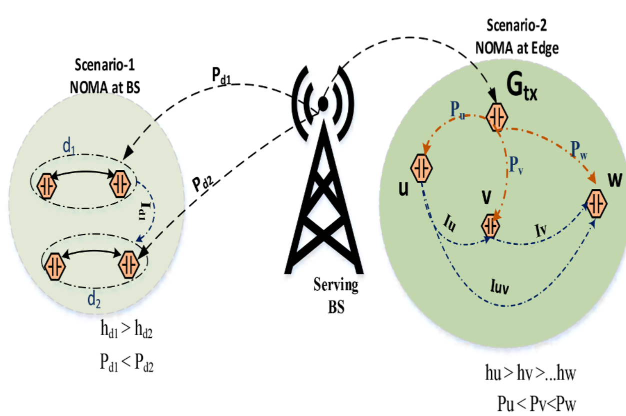


Fig. c NOMA-at BS &NOMA-at-Edge scenario

A. Explanation on impact on interference

To evaluate the impact on the interference of the Group-NOMA-D2D and NOMA-D2D approach. A scenario is shown in Fig. Let us suppose one NOMA-Group namely GNP1 consisting of three group receiver nodes and two D2D pairs namely $d_1,\ d_2$ are present. In GNP1, $J \in \{u,v,w\}$, here, J is the set of sensor nodes in the group. Here the interference for the u^{th} sensor node is I_B, v^{th} sensor node receives interference from $I_{BS} + I_u$, and w^{th} sensor node receives from $I_B + I_u + I_v$. Where $I_u = P^R_{GH}|h_{u,q}|^2$ and $I_v = P^R_{GH}|h_{v,q}|^2$. whereas in NOMA-D2D approach d_2 pair D2D receives interference $I_{d_2} = P^q_{BS}|h_{d_1}|^2$.Since P^q_{BS} is much greater than the P^R_{GH}, this signifies the interference bear by the nodes with NOMA at edge approach is more promising for green communication than NOMA at BS approach 0for urban farming in multistory buildings using NB-IoT.

B. Resource re-utilization concept in Group-NOMA-D2D approach

In the case of the Group NOMA-D2D approach, the Group head demand for 1PRB $\sim=$ 180 kHz. Consider the case the Group-1 has 2 receiver nodes and one transmitter node/Group Head and each device is required to transmit small text data, hence require 15 kHz bandwidth only. Whereas Group-2 has 3 receiver nodes and one transmitter node/Group Head and each device is required to transmit large text data, hence each receiver (sensor node) requires 45 kHz bandwidth.

Thus utilizing Fuzzy logic GH_1 will allocate 15×2= 30 kHz bandwidth, and append the left resource (180–30 = 150 kHz) to the next iteration. Whereas the GH_2 will allocate the 45×3=135 kHz bandwidth and append the left resource (180- 135 = 45 kHz) for the next iteration. Hence in the next iteration, GH_1 will not request for uplink resource allocation and utilize the left resource grant. However, GH_2 will request for the PRB whilst utilizing the left resource.

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