Routing and Clustering for Ultra High Dense Networks

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Content

1. Future networks features.
2. Ultra High Dense networks.
3. Nodes loading.
4. Combined criteria.
5. D2D networks.
6. D2D network clustering.
6. Transit node location.
7. SINR value or RSSI value clustering.
8. Conclusions.

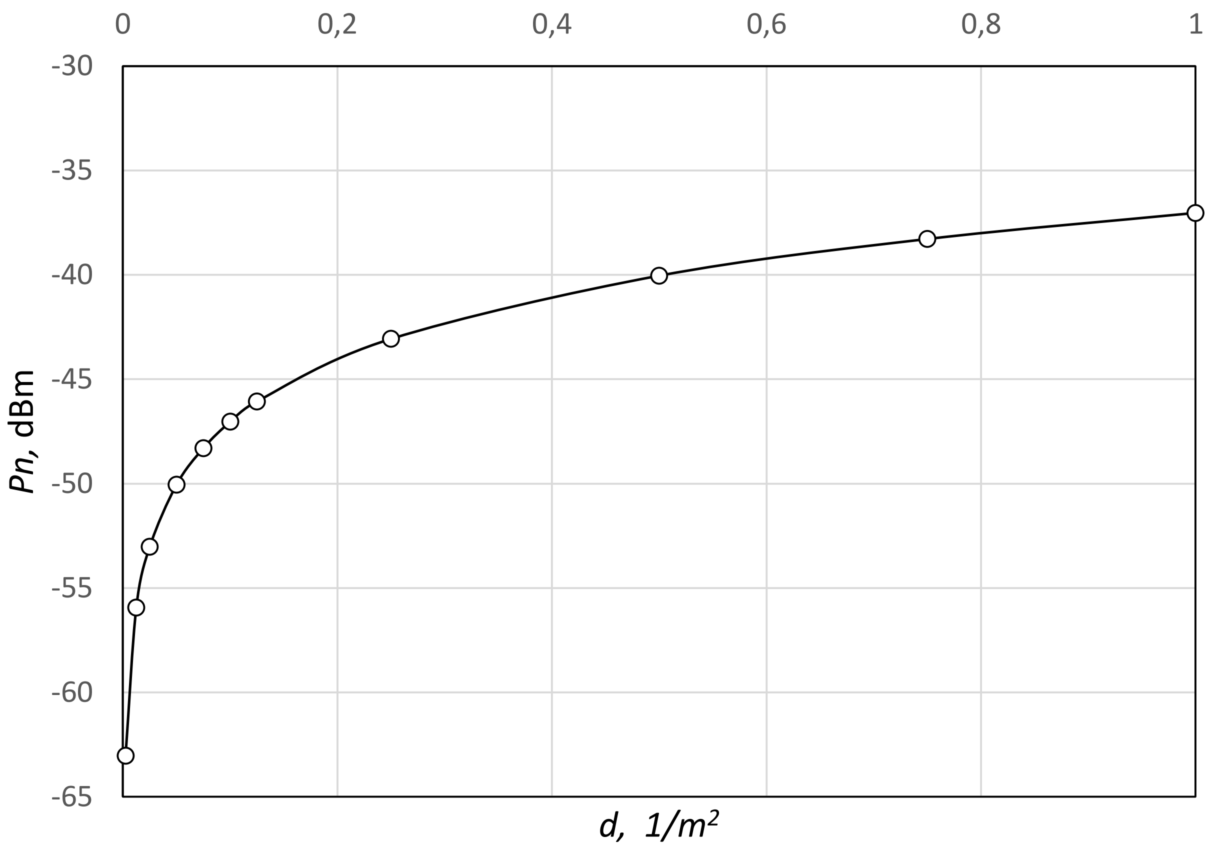
Future Networks Features

- Ultra High Dense
- Ultra Low Latency

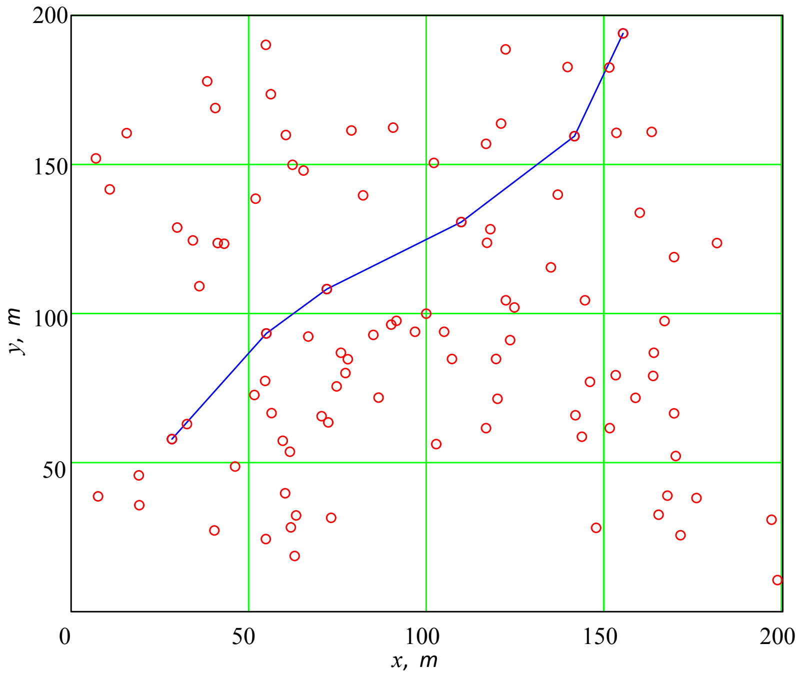
Ultra High Dense

- 1mln device per 1 square kilometer
- The need to serve traffic within common interest groups, the community, universities, etc. without loading the network core.
- D2D communications
- D2D networks

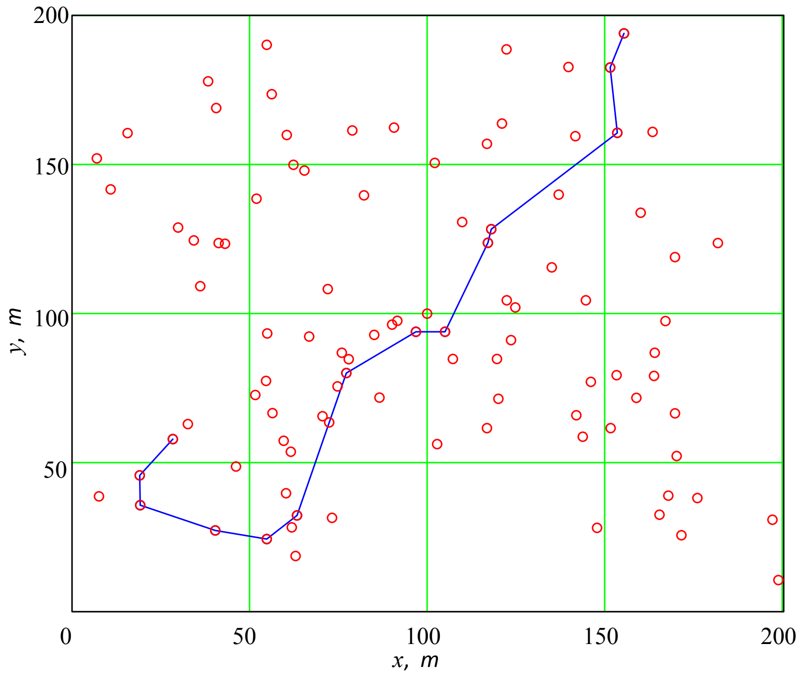
Dependence of interference power on the density of network nodes at a power level of each device of 20 dBm.



Ultra High Dense Networks

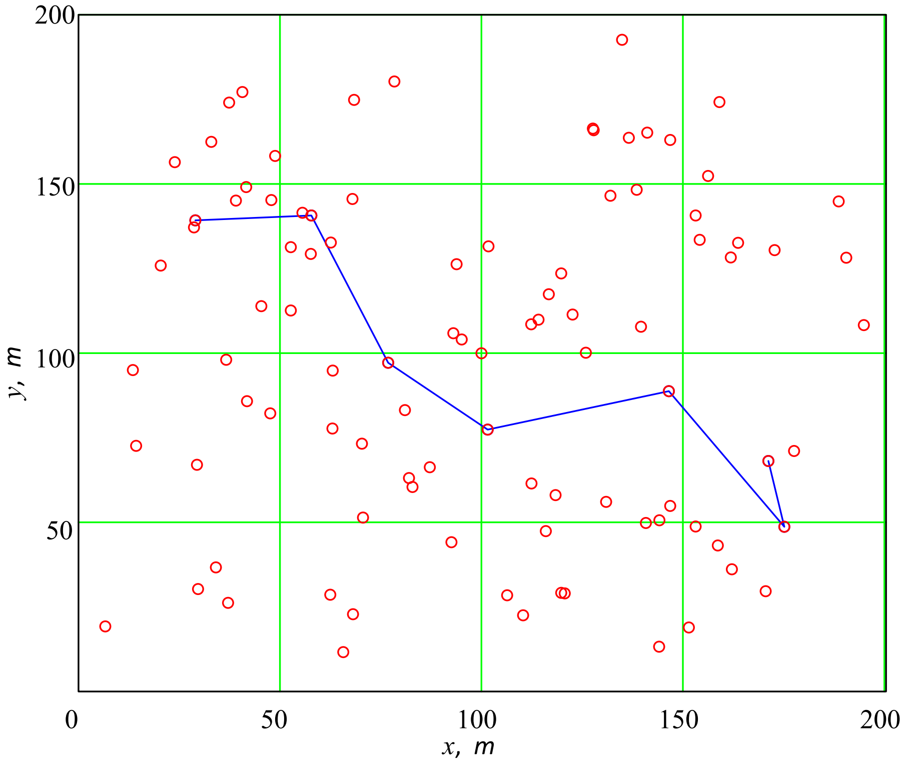


The minimum path

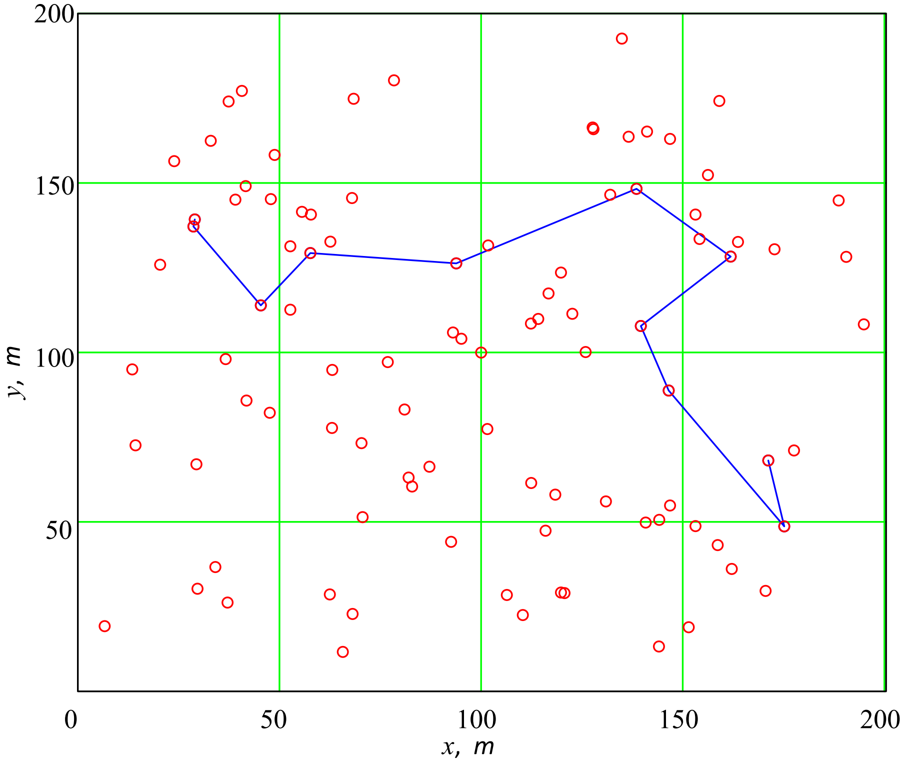


The bandwidth maximum

The nodes loading



Without loading accounting



With loading accounting

The role of nodes loading (interference due to loading)

- Taking into account the interference produced by the signals of the network nodes, significantly affects the choice of route. An analysis of the results of simulation showed that, compared with the route selected by the distance criteria (the shortest in the sense of distance), the average number of transits (jumps) increases. This is explained by the choice of paths with a maximum SINR ratio, the magnitude of which is inversely proportional to the distance between the transmitting and receiving nodes. The increase in the number of transits, in general, is a factor negatively affecting the quality of the route, therefore, it is advisable to take it into account when searching for a solution. A complex criteria for choosing a route for maximum throughput and minimum number of transits will proposed further.

Combined criteria

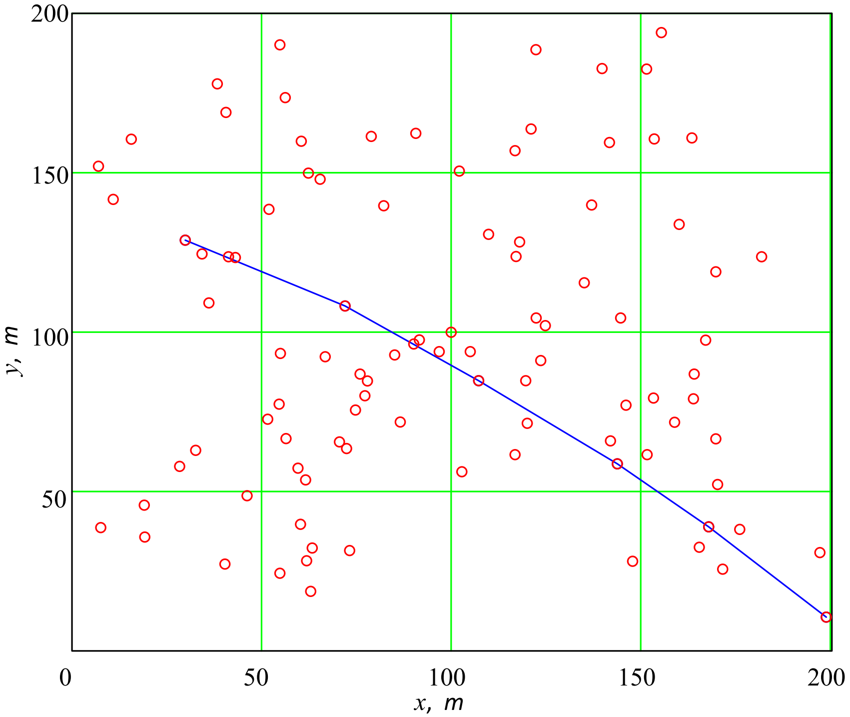
If the difference between SINR (i,j) and min (SINR (i,k), SINR (k,j) is small then the choice of additional transit through *k*-th node is not advisable.

$$SINR_{ij} = \begin{cases} \max\left\{SINR_{ij}, \min\left(SINR_{ik}, SINR_{kj}\right)\right\}, & \left|SINR_{ij} - \min\left(SINR_{ik}, SINR_{kj}\right)\right| > \varepsilon_0 \\ SINR_{ij} \end{cases}$$

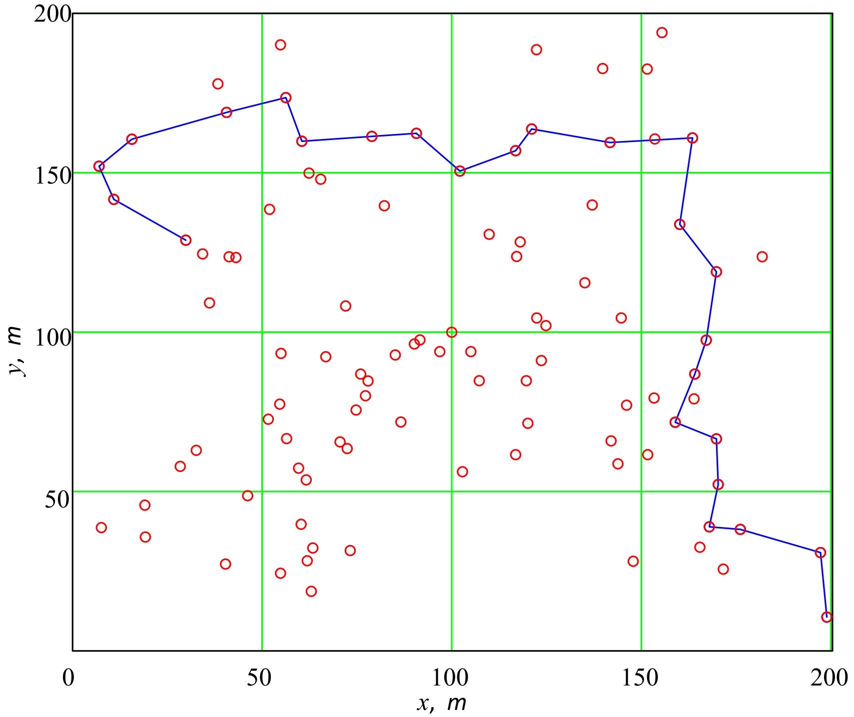
Selection of ε_0 value

- To select ε_0 we will proceed from the following considerations. An increase in the number of transit nodes in the route increases the traffic produced in the network (using the distribution medium), and therefore, the interference power for other network nodes, thereby reducing the SINR ratio for them. We assume that the decision to choose an additional transit node is advisable only when the gain expressed in previous slide exceeds the decrease in the SINR value for the remaining nodes.

Comparison (1)

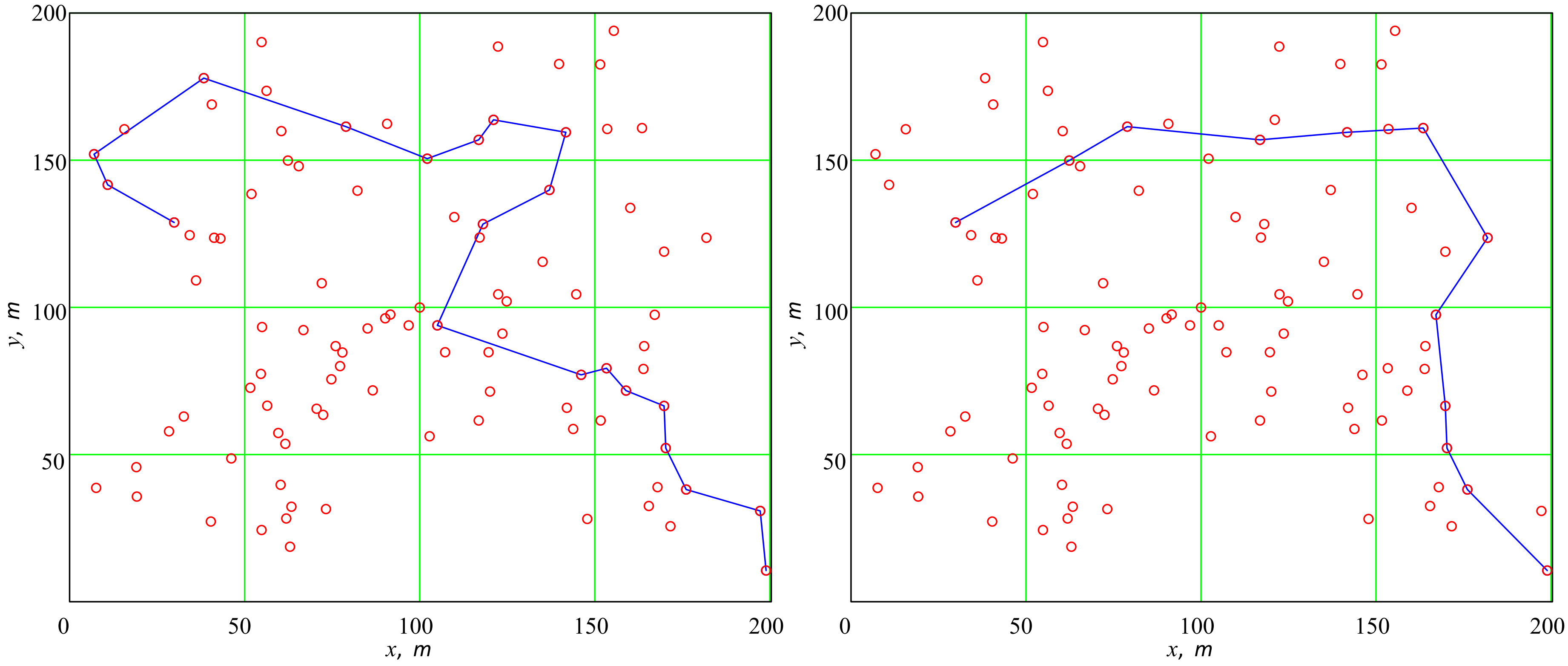


The minimum path



The bandwidth maximum

Comparison (2)



Combined criteria

$\mathcal{E}_0 = 2\text{dB}$ $\mathcal{E}_0 = 5\text{dB}$

Comparison (3)

- Slides 11 and 12 show the results of route simulation using the criteria of length, maximum throughput and the combined criteria. The shortest route contains the minimum number of transits (4 transit nodes). The route selected taking into account the throughput (assuming that the traffic intensity of all nodes is equal) contains 30 transit nodes. The results obtained using the combined criteria contain 18 and 10 transit nodes. The difference between the last two results is that in the first case the critical value $\mathcal{E}_0$ is 2dB, and in the second case $\mathcal{E}_0$ equally 5dB.

Comparison (4)

- The application of simple criteria for choosing a route according to one of the parameters gives particular solutions, which may turn out to be practically unsuitable due to too many transits, as well as ignoring the influence of the chosen route on other network nodes.
- The proposed route selection method using the combined criterion makes it possible to find a compromise between the route length (number of transits) and the quality of the route.

D2D Network

- The D2D communications in the ultra high dense conditions establish a D2D network.
- In determining the interference, traffic that is generated in dense networks in the route sections must be taken into account.
- The route of the shortest length can no longer be considered optimal.
- The development of new protocols for ultra high dense networks using technologies D2D is required.

D2D network clustering (1)

Moving from considering D2D as soon as interactions to creating D2D networks, it is necessary to provide transit functions for individual nodes of the D2D network. Only in this case we get a D2D network, and the number of transit nodes in one connection, strictly speaking, is not limited.

In any case, it is not advisable to use the terminals of mobile network users for additional routing, since there are no well-established procedures for the mutual accounting of energy consumption and the provision of services with better parameters.

D2D network clustering (2)

In connection with the above, it is possible to achieve the desired goal, first of all, by introducing additional nodes into the network - terminals, which will take on functions that are undesirable for users. So, if the functions of routing and transit nodes will be performed only by input nodes, then user terminals will not incur additional energy costs. As such input nodes, standard terminals of communication networks belonging either to the communication operator itself or to the provider operating in the territories of sports centers, shopping centers, etc. can be used.

D2D network clustering (3)

- Moreover, the introduction of adequate additional routers in the network will, if necessary, provide the functions of legal traffic interception.

Transit node location

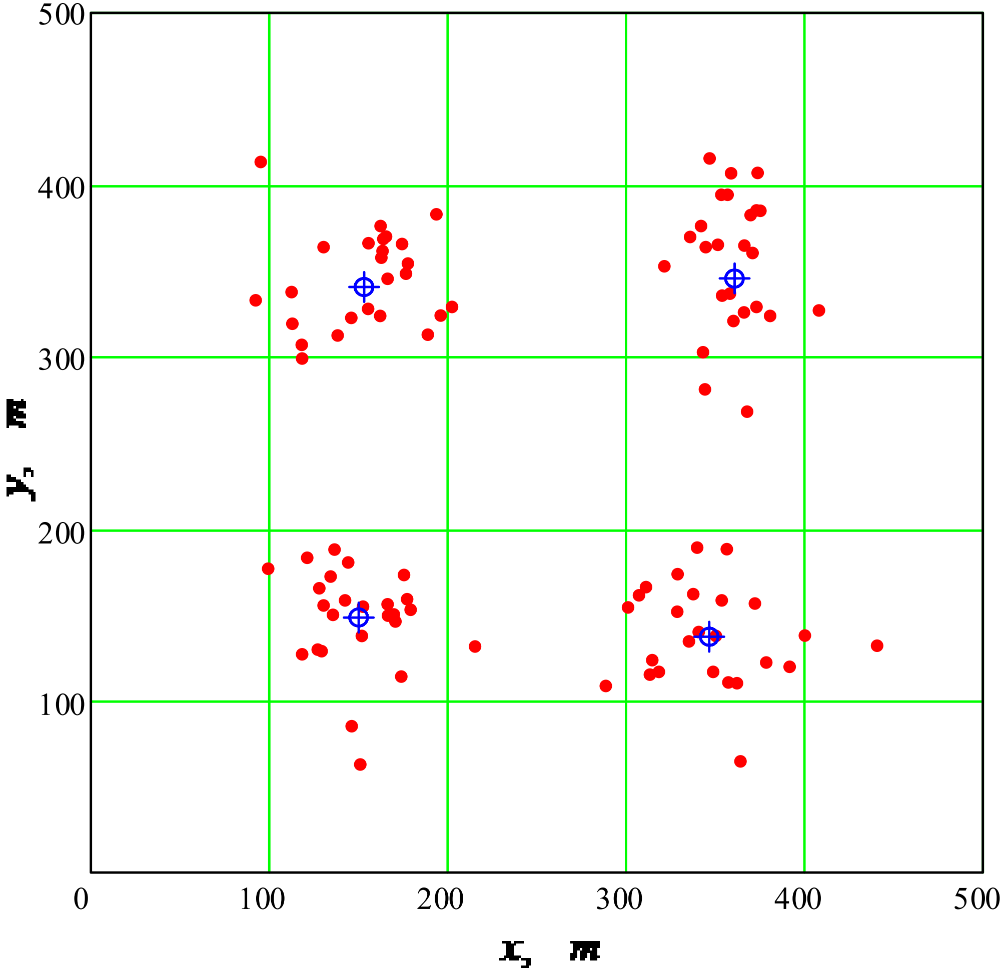
- The selection of the location of the transit node can be considered as the task of choosing a set of nodes (for which it will be transit) by some criteria. It is advisable to use the SINR value as such a criteria. The criteria for selecting nodes in a group of nodes will be following SINR $(x,y,i) \geq S_0$

Optimization procedure

FOREL algorithm, objective function

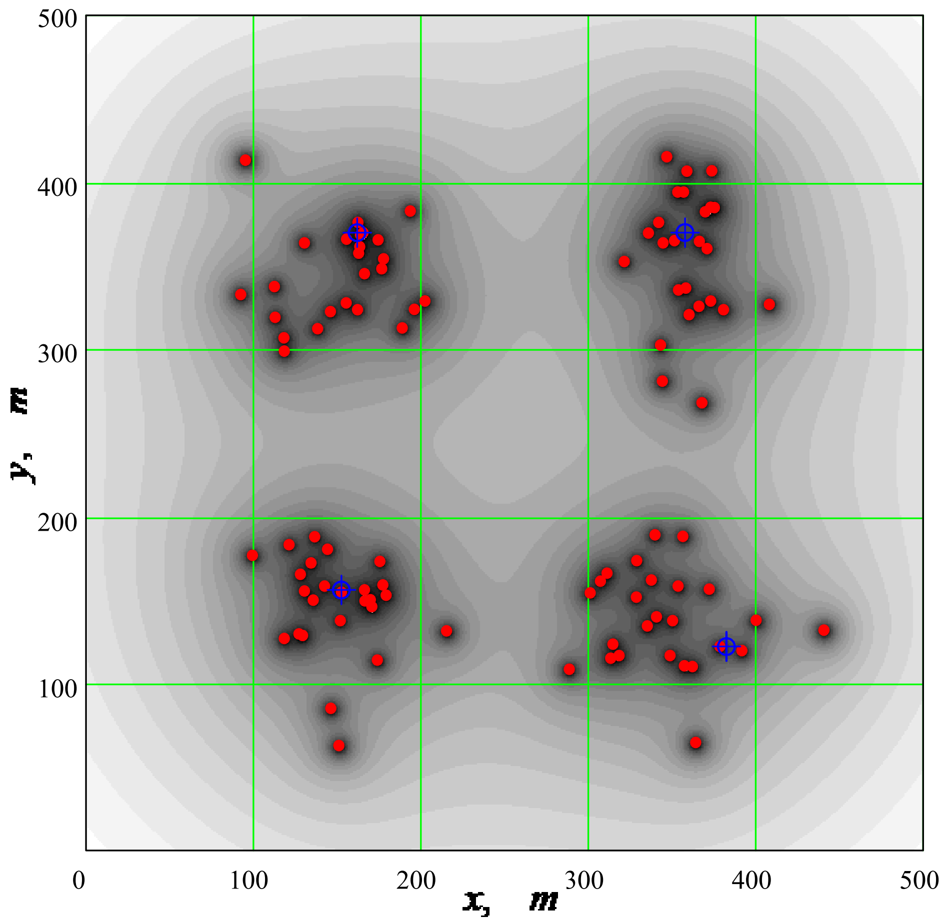
$$\max_{\mathbf{N}_j} \sum_{j=1}^{k} \sum_{i=1}^{N_j} SNIR(x, y, i)$$

Transit nodes location (1)



by criteria of minimum RSSI> -60 dBm

Transit nodes location (2)

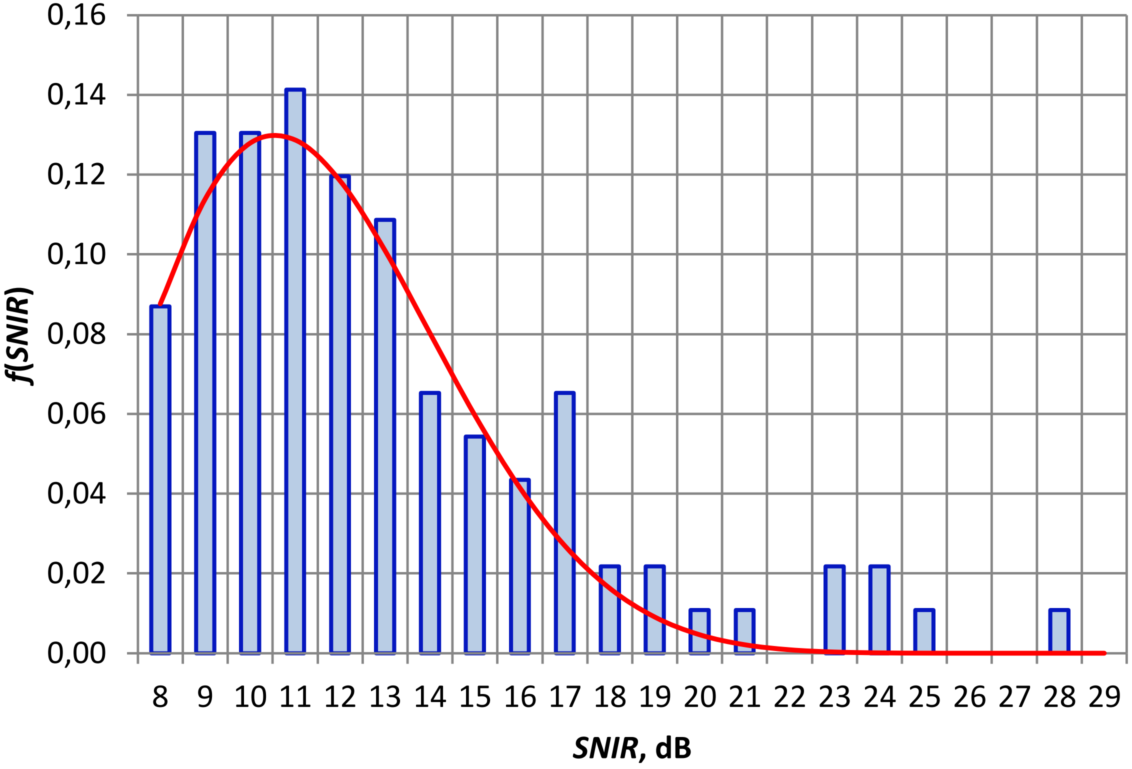


by criteria SINR> 8 dB

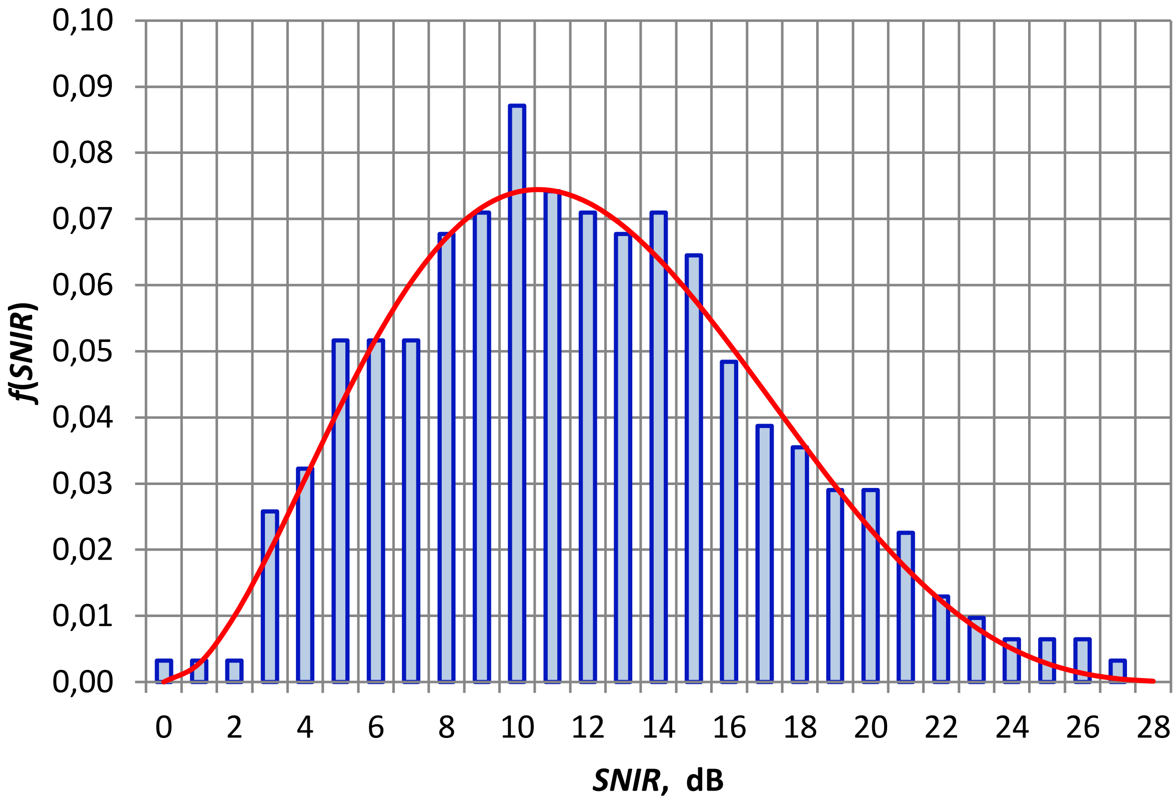
Comparison

- The number of transit nodes is the same, but the position of the points of location of the transit nodes when taking interference into account is different. The average SINR in the cluster also differs, taking into account interference, it is on average 3.8 dB higher (in this example). Therefore, in this case, a higher throughput is provided.

SINR distribution (SINR value clustering)



SINR distribution (RSSI value clustering)



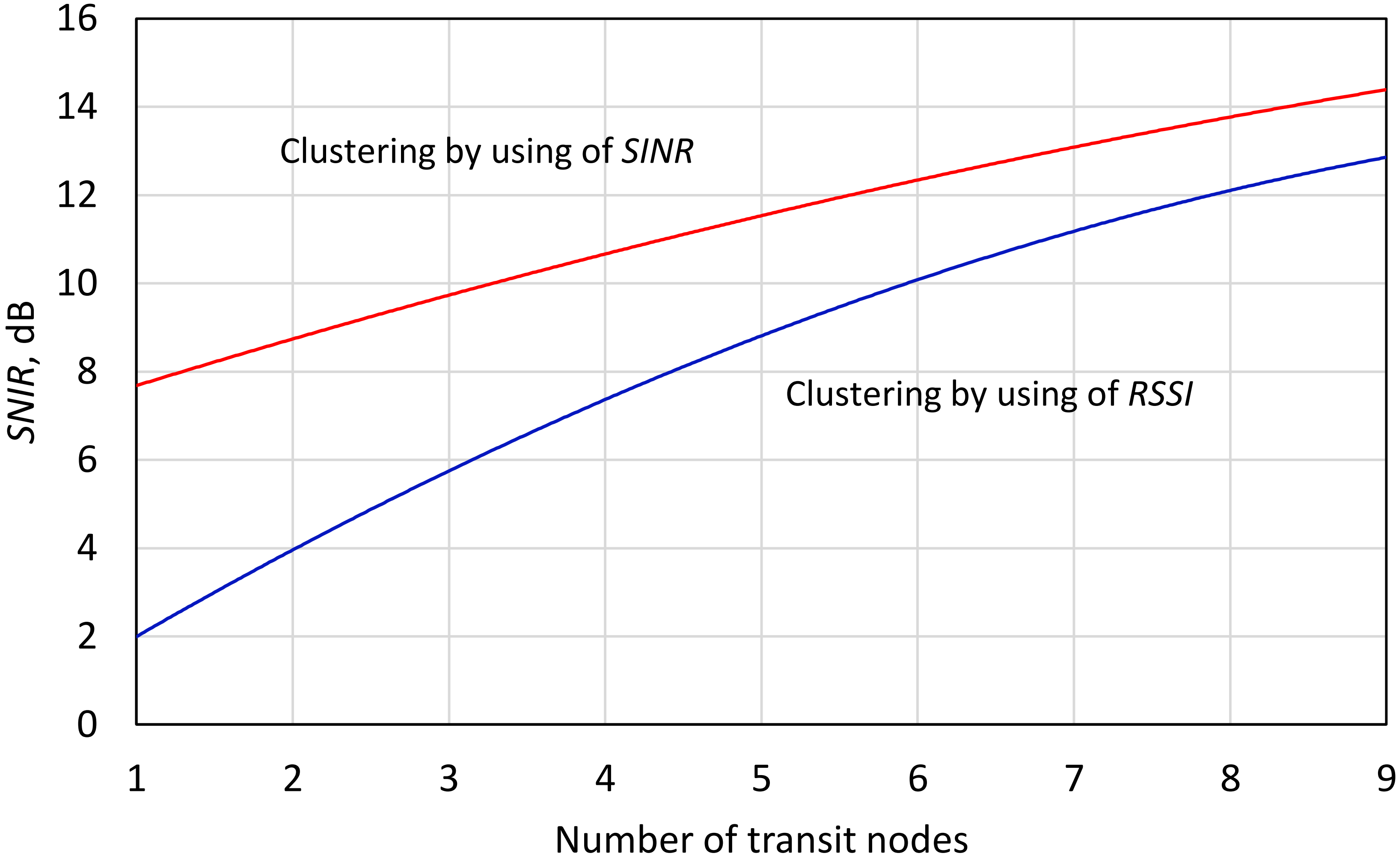
Comparison (1)

- The distribution for SINR case is limited below by the value of the threshold value, and above by the value of the maximum attainable value, which is determined by the parameters and configuration of the network (in this case, 28 dB). The average value was 13.70 dB and the standard deviation was 4.3 dB. The distribution obtained as a result of clustering by RSSI value is of a similar nature, with the difference that its lower boundary is determined by the network parameters, as well as the upper one. The average SINR in the second case is 11.75 dB, the standard deviation is 5.8 dB.

Comparison (2)

- In this case, the gain that the proposed algorithm gives is about 2 dB for the average value and 1.5 dB for the standard deviation. Thus, the solution obtained by the proposed method allows one to obtain a larger bandwidth (on average, 5 Mbit / s for the 802.11n standard) and its smaller spread for network nodes compared to the method that does not take into account the influence of interference. Also note that in clustering without interference, the real SINR ratio in some cases is less than 2 dB, which is practically corresponds to zero bandwidth.

Comparison (3)



Comparison (4)

- The effectiveness of the proposed method is higher than with clustering without taking into account interference, and a greater gain occurs with a relatively small number of transit nodes. With an increase in the number of transit nodes, the gain decreases, but with real values of the number of nodes it is of significant importance.

Conclusions (1)

1. Moving from considering D2D as soon as interactions to creating D2D networks, it is necessary to provide transit functions for individual nodes of the D2D network. Only in this case we get a D2D network, and the number of transit nodes in one connection, strictly speaking, is not limited.

Conclusions (2)

2. The application of simple criteria for choosing a route according to one of the parameters gives particular solutions, which may turn out to be practically unsuitable due to too many transits, as well as ignoring the influence of the chosen route on other network nodes.

3. The proposed route selection method using the combined criterion makes it possible to find a compromise between the route length (number of transits) and the quality of the route.

Conclusions (3)

4. The SINR value clustering is more better than RSSI value clustering for Ultra High Dense Networks.