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Code Allocation in Clustered Based MAC in Mobile Adhoc Networks

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Abstract

In this paper, I have proposed a clustered based CDMA MAC protocol for MANETs. At first the proposed clustering algorithm divides the network into some one hop overlapping clusters. In each cluster, the cluster-head uses a pool of orthogonal disjoint code sets to assign codes to its cluster members. Each cluster and its neighbouring clusters use different code sets and these sets are reused in the network. The number of codes sets in the pool and the number of codes in each set is determined by the neighbour degree of a cluster and the number of nodes in a cluster. Instead of assigning codes to all the nodes in a cluster, I have proposed a new assignment scheme that assigns codes to the nodes presently involved in communication. It helps to decrease the code requirement in the system. I have compared our protocol with the TCA and PCA based scheme and shown that the requirement of code, the proposed protocol is lesser than TCA but more than PCA. Though the requirement of code in PCA is the least, but it takes expensive hardware and its implementation is difficult. Considering the mobility and the remaining energy levels of the nodes, cluster-heads may release their headship and new clusters are formed. With the help of simulation, I have studied the formation of such clusters by varying the load on the system.

Keywords—MANET, CDMA, MAC, Cluster, OMnet++

1. Introduction

Mobile Ad hoc networks (MANETS) are infrastructure-less, multi-hop, dynamic topology based wireless networks, where all nodes have arbitrary mobility and act as either host or router for forwarding packets to other nodes in the network. Since it is infrastructure-less, the deployment of MANET is easy and costless and it supports various applications, namely close-group message sharing, disaster managements, battlefield communication etc. Mobile ad hoc networks have got a widespread amount of interest.

Designing efficient MAC protocols for MANET [12-14] and WSN is a challenging task because the networks are wireless and the nodes are energy constrained. The contention based medium access (MAC) protocol IEEE 802.11 was broadly used for wireless LAN networks, but due to its disadvantages like hidden terminal and exposed terminal problem, it is not always a good choice to use it in MANETS and WSNs. The RTS/CTS packets used in contention-based protocol has large overhead [10]. Contention free MAC protocol CDMA added high interest for MANETs. Code division Multiple access (CDMA) may come very handy in Mobile Adhoc Network (MANET) as well as in sensor network. CDMA is using spread spectrum (SS) techniques, and occupies the entire bandwidth.

Code assignment schemes for CDMA can be divided into three types: transmitter-based code assignment (TCA), receiver-based code assignment (RCA), and pairwise-based code assignment (PCA) [5, 6]. In RCA, each terminal is allocated a receiving code where no two neighbours of a node use the same code. Hidden terminal interference problem cannot be completely solved by the RCA scheme while it can be totally removed by properly assigning codes in the TCA [2, 8]. In TCA, neighbour nodes of a node use different codes for transmitting. PCA scheme allocates codes to transmitter-receiver pair where no two adjacent edges have the same code. For the PCA scheme, it conserves the same interference avoidance properties of the TCA one, while requiring a more costly hardware and a fewer code, and yields a worse performance [5, 2]. In this paper I propose a new clustering algorithm and a new dynamic and adaptive code assignment algorithm.

1) Construction of this Article

In Section 2, I have discussed the related work on MAC protocols. System model, clustering and code assignment are discussed in section 3. In section 4, simulation and results are shown and finally conclusion in given in section 5.

2. Related Works

In the paper [5] L.Hu has given a distributed algorithm of code assignment in a packet radio network. Here the algorithm has been devised in two phases to assign and reassign the codes to receivers, transmitters, and the pair of nodes in a large packet radio network.

Dow, Lin, and Fan [3] proposed a clustering based two level code assignment algorithm for ad hoc wireless network. To avoid the hidden terminal problem, in the first level some cliques are formed in each cluster and assigned a different code to a different clique in a dis- tributed manner. In the second level to reuse the code, selected node is chosen, which reassigned the codes to the cliques for minimizing the number of codes in the whole network. Here the problem is, the load of the selected node is too much in the second level.

In a related work, Bertossi and Bonuccelli [2] introduced a centralized code assignment scheme and a fully distributed code assignment scheme for the overall network. Dow, Lin, and Fan [3] proposed DS-CDMA in clustered wireless networks to remove the hidden node problem. It has high throughput, low packet latency and energy saving. Muqattash and Krunz [9] proposed a CDMA MAC protocol for ad hoc networks where, RTS/CTS are used to decrease the transmission energy of a node in the neighborhood of a receiver.

Liu, Chou, Lipman, Jha [7] discussed frequency division to diminish the MAI in a DS-CDMA sensor network. Each pair of sensor nodes are allocated different frequency band where no interference happens in the neighbouring nodes.

FDMA is another contention free MAC protocol which generally works with CDMA or TDMA in wire- less network. MAC protocol consists of more than one existing MAC protocols, is called a hybrid MAC protocol. In a wireless network, several works have been done on the hybrid MAC protocol where any two of the contention free protocols are combined.

Haas and McLaughlin [4] considered dynamic channel assignment (DCA) technique for a combined TDMA/CDMA with TDD interface where neighbouring cells are allocated channels with different symmetry. Al-Mandi et al. [1] proposed a channel assignment scheme for CDMA/TDMA mobile networks that confirms QoS and provides successful voice transmission as well as data traffic. In [11], a dynamic channel assignment scheme, Hybrid-DCA was discussed for a clustered mobile ad hoc network with CDMA/TDMA.

3. Cluster Based Code Assignment in CDMA Protocol

In a CDMA based system, users are assigned different "codes". A problem in using CDMA in ad hoc network is to assign "codes" to different nodes and it is updated with the change in topology. In our work I have proposed an efficient clustering algorithm followed by a code assignment algorithm. I have compared the proposed code assignment with some standard code assignment techniques TCA and PCA. It is shown that the code requirement on our system is lesser than TCA. Though the PCA scheme takes lesser code than the proposed scheme but its implementation is not easy and needs expensive hardware. Proposed code assignment algorithm is adaptive to changes in the network topology.

1) System Model and Analysis

In this section, I have discussed our proposed model. At a given instant of time MANET is represented as a directed graph G = (V, E), where V denotes the set of nodes and E represents the set of logical edges. For any two nodes V_x, $V_y \in V$, a logical edge $E_{x,y}$ exists, where $E_{x,y} \in E$, that implies V_x has a wireless channel to V_y . The system is partitioned into a set of clusters C = C_1, C_2,…, C_m by running the clustering algorithm. A clustering-based wireless network can be represented as a triplet G = (V, E, C), where C denotes the set of clusters. Each node is a part of one cluster. Hence, three conditions are required:

1. $C_i \neq \emptyset$ for $1 \leq i \leq |V|$.
2. For any $C_i, C_j \in C, C_i \cap C_j = \emptyset$.
3. $\cup C_i \in C\{V_x : V_x \in C_i\} = V$.

For instance, four clusters, C_1, C_2, C_3, and C_4 in Figure 1 are within the system. Let N_x denotes the members of cluster x. CH is the set of cluster-heads in G. In Figure 1, the system shows four clusters divided by the clustering algorithm 1 where the set CH contains the nodes V_1, V_2, V_4 and V_7, i.e. CH = V_1, V_2, V_4, V_7. A gateway node which directly connects to more than one cluster-heads. GT is defined as a set of gateways in G. In the figure, GT = {V_9, V_{11}}. Similarly IN is a set of intermediate nodes in G which connects two cluster-heads by two or more hops. Ac- cording to the figure, IN = {V_3, V_5}. OD is a set of ordinary nodes that are not a cluster-head, gateway, and Intermediate node, where OD = {V_6, V_8, V_{10}}.

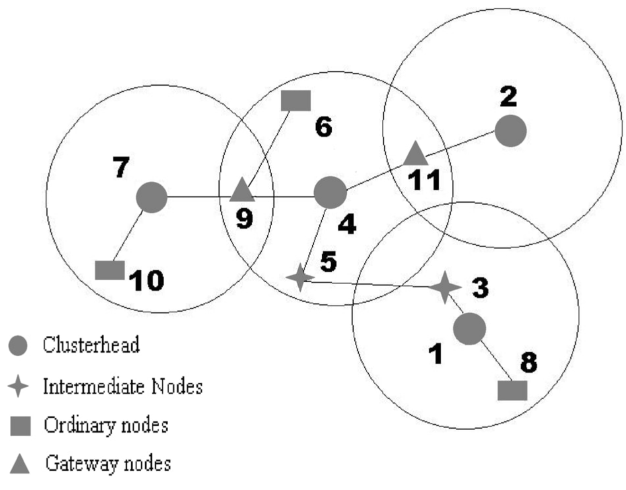

Fig. 1 Cluster based ad hoc wireless network.

2) **Assumptions:**

1. All messages are transmitted without loss.
2. The nodes are moving very slowly and are stationary for a sufficient amount of time needed for assigning the codes.

2. Clustering Algorithm

The clustering algorithm 1 is used to form one hop clusters. Firstly, every node calculates its degree through the neighbour discovery and broadcast the degree information to their neighbours. The node M chooses itself as cluster-head if it has maximum degree among its neighbours. If it selects itself as cluster-head, it communicates the membership request message to its neighbours. When a node gets a membership request message from a cluster- head and if it is not a member of any cluster, it accepts the request for being the member of the cluster-head by sending a positive acknowledgement ACK. If a node overhears the positive acknowledgements from all its higher degree neighbours, it selects itself a cluster-head provided it is not a member of any cluster. When any cluster-head receives a ACK message from a node j, selects it as a cluster member. I have considered that the node which selects itself a cluster-head, reduces its speed and moves very slowly. It makes the clusters more stable and the cluster-heads remain as cluster-heads for a long time.

At the time of cluster formation, each cluster-head identifies the gateway nodes and the intermediate nodes. Whenever a node receives a new membership request message from a cluster-head and if it received a similar message from other cluster-head earlier, it broad- cast a gateway message mentioning all the node-ids of its neighbour cluster-heads. The cluster-head, which receives the broadcast message, considers the sender node as the gateway of the neighbouring cluster/clusters. When a node overhears some message from a node, be- longing to a different cluster-head, it informs its own cluster-head to consider itself as the intermediate node between these two clusters. Cluster-heads use the sets GT and IN for storing the gateway nodes and the in- termediate nodes respectively.

All the data in a cluster goes through a cluster-head. As a result, cluster-heads loose energy faster than the other nodes. Thus I propose that the cluster-head will remain as cluster-head as long as its remaining energy is at least a cut-off energy (E_{cutoff}) value. Once the energy of the cluster-head goes below this cut-off value, it releases the cluster-head responsibility by informing its cluster members (negative acknowledgement packet) and becomes a normal node. Cluster members and the old cluster-head again select a new cluster-head by using same procedure. The cut off value is a variable which is equal to half of the energy value noted when the node becomes the cluster-head.

M_i = Node with maximum degree

CM_i = Cluster- head i requests for cluster member.

ACK_i=Node I sends positive acknowledgement.

GT_i= Gateway nodes set in cluster i.

IN_i= Intermediate node set in cluster i.

Algorithm 1 Clustering Algorithm

$\forall$ Do

i, 1 to n in parallel

Node V_i broadcast the neighbour degree to all its neigh- bours

Node V_i calculate M_i

if $(V_i = M_i)$ **then**

Mark itself as cluster-head CH_i

Broadcast a message CM_i for requesting its neighbours for being cluster member

end if

if (received CM_k) **then**

if (not a member of any cluster) **then**

Send ACK_i to cluster-head k

else

Broadcast a "gateway message", which includes all the cluster-head ids from where it received CM messages

end if

end if

if (Received any message from a node belongs to other cluster j) **then**

Send an "intermediate message", which contains id j to its cluster-head

end if

if (cluster-head received "gateway message" from node *k*) **then**

Add this node *k* into set *GT* as the gateway node for the cluster-heads mentioned in the received message

end if

if (Received any "intermediate message" from node *m*)

then

Add this node *m* into set *IN* as an Intermediate node for the cluster-head mentioned in the received message

end if

EndDo

3) Complexity of Clustering Algorithm

Let us consider the number of nodes in the network to be n. After a neighbour discovery, each node sends its degree information to its neighbours. Thus, total number of such messages are n. Some of the nodes, who be- come the cluster-heads send membership request messages and the rest of the nodes send the acknowledgements. Thus, as a whole cluster-heads and the member nodes send n messages. The nodes which become a gateway node and intermediate node send maximum n more messages. So total number of messages exchanged by the proposed clustering algorithm are O(n).

4) Code Assignment

Inside a cluster all the communications are done through the cluster-head and inter-cluster communication is done between the cluster-heads through the gateway nodes and intermediate nodes. For simultaneous intra-cluster or inter-cluster communications, I have proposed CDMA based orthogonal code assigned to the nodes. Codes are assigned to the nodes in such a way that no primary or secondary interference occurs in the network.

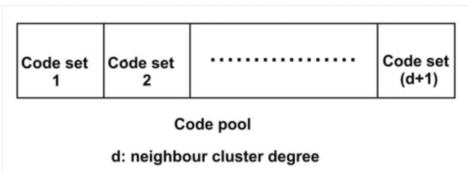

Fig. 2 Code pool of disjoint code sets.

I have considered that the number of nodes in the network is n and out these, maximum half of the nodes communicate at some time instant. Thus, if there is C clusters formed in the network, then number of communications happened at any time instant inside a cluster n/2C. So if each cluster use maximum n/2C number of codes for its members then member nodes can freely communicate with their cluster-heads. These sets of codes must not be used in the neighbour clusters, but can be reused in the clusters which are more than R (communication range) distance away. Thus, if there are maximum d number of neighbour clusters of each cluster then total number of orthogonal codes required n(d+1)/2C.

I have considered d + 1 number of code sets in a code pool, where d is the neighbour cluster degree of a cluster. Every cluster-head use same pool of codes and assign one of the sets to the nodes who are involved in communication. The set of codes used by a cluster is different from the neighbouring clusters. Figure 2 shows the code pool of d + 1 numbers of disjoint code sets.

5) Comparison of Code Assignment Techniques

There are three types of Code assignment schemes for CDMA- transmitter-based code assignment (TCA), receiver-based code assignment (RCA), and pairwise-based code assignment (PCA) [5, 6]. TCA scheme performs better than RCA because in the later one, hidden terminal interference cannot be totally evaded. On the other hand PCA scheme is better than TCA and RCA in terms of code requirement, but its implementation is difficult and needs more complex hardware.

Here I have compared our code assignment technique with TCA and PCA. In our proposed system, transmitter-based code assignment is used to assign codes to the nodes inside each cluster. Let us consider, the node degree of the network is Δ. Inside the cluster, the degree of the cluster-head is also same. Thus, in the average case if half of the nodes in a cluster communicate with the cluster-head at some time instant, then it needs Δ/2 codes. If a cluster has a d number of neighbour clusters, then the total code requirement in our proposed system is (d+1)Δ/2 codes.

On the other hand, the number of code requirement for the standard TCA based system is $\Delta(\Delta - 1)$. The difference between the TCA and the proposed system is that in the later case code is assigned to the nodes after the clustering process. Thus, it can be stated that the code requirement for the TCA system is more than the proposed system, if $(d+1)/2 < (\Delta - 1)$. For an average dense network,(d + 1) is generally lesser than the $(\Delta - 1)$. In the simulation section, I have shown it in the Figure 4. In the case of PCA based system, the code requirement is $\Delta + 1$, which is lesser than TCA as well as the proposed system. But main draw- back of PCA based system is the requirement of costly hardware and its implementation is difficult.

6) Mobility Issue on Clustering and Code Assignment

If an ordinary node moves out of a cluster and joins another cluster, it sends a leaving message to the old cluster-head and then sends a join message to the new cluster-head. As told, a cluster-head may leave its head- ship when its energy goes down below a predetermined energy level, E_{cut_off} . Then a new cluster-head is elected in its place and the new elected cluster-head consults its neighbouring cluster-heads to select a code set from the code pool. Though it is considered that the cluster- heads move very slowly, but sometimes a cluster-head may leave its headship when it comes within the trans- mission range of another cluster-head. In this case the higher energy cluster-head remains as the head and an- other one becomes an ordinary node. The nodes which loose their head, may elect a new cluster-head, in absence of any other cluster-head within their transmission range.

4. Simulation Results

This section presents a simulation environment and results. A network with N nodes is taken where N ranges from 10 to 50 with an interval of 10. These nodes are placed randomly on a 600 x 600 squareunits area. The transmission ranges were varied from 100 to 250 units. Each node is considered as battery operated and has an initial capacity of 50 Jules. Simulation is done in Omnet++ simulator software.

In the first set of simulation, I have implemented our proposed clustering algorithm and studied the followings (1) Formation of clusters with changing the trans- mission range of different node number. (2) Formation of clusters with changing the node number for a fixed transmission range.(3) Maximum number of nodes in each cluster for different transmission range. Figure 3 represents the formation of clusters with the variation of the transmission range. The number of generated clusters decreases with the rise of the transmission range. In this case, the total number of nodes is fixed and cluster size increases with the increase of transmission range which accommodate more nodes in a cluster.

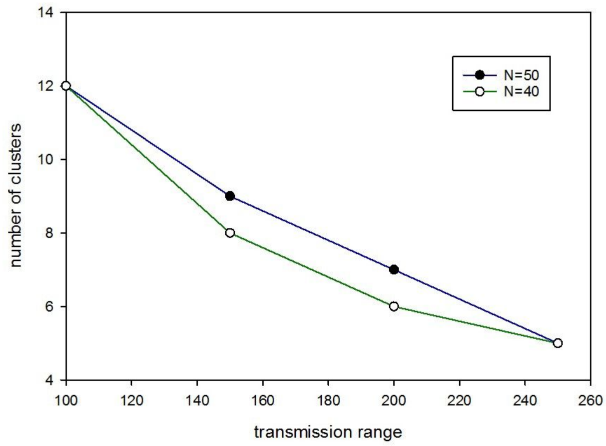

Fig. 3 Number of clusters with different *R* for 50 and 40 nodes.

Thus, less number of clusters are formed. Number of generated clusters generally increase with the rise of the number of nodes which is also depicted in the same figure. In Figure 4, I have shown how the number of clusters increases with the increase of number of nodes for a fixed transmission range (150 units). In the same figure I have also shown the maximum neighbour cluster degree (d) and the maximum degree of the network (Δ) for different number of nodes. It is found that the d is always lesser than Δ and both of them generally increase with the increase of the density of the network. When nodes are increased, more number of clusters are formed to accommodate all these nodes. During these simulations, I have also noted (shown in Figure 5) the maximum number of nodes in each cluster with the variation of transmission range for number of nodes being 50 and 40. As transmission range increases, more nodes are accommodated in each cluster and it rises with the rise of nodes in the network.

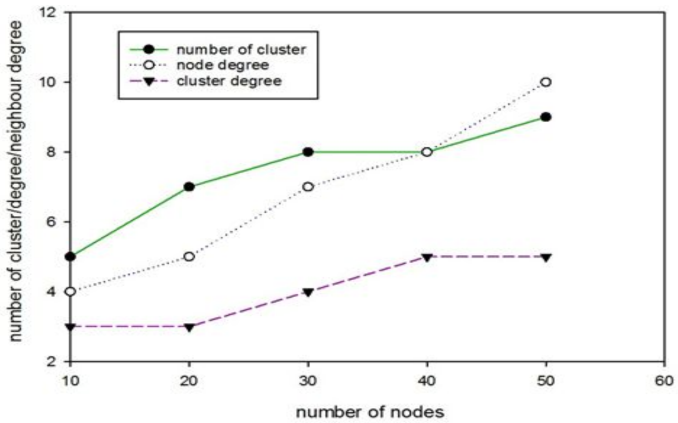

Fig. 4 Number of clusters, *d* (cluster degree) and ∆ (node degree) with different node number.

In Figure 6, I have compared our proposed code assignment with the standard techniques TCA and PCA. The maximum number of codes that are required for the system is shown in the figure for these three different techniques for a fixed transmission range (150 units). From the figure, it is found that our proposed system needs a lesser number of codes, compare to TCA, but it is more than the PCA. As the nodes are increased in the network, code requirement is increased in all the techniques. Though the code requirement of the PCA is the least, but its implementation is costly and complex.

I have already discussed that cluster-heads release their headship when their energy goes down below the cut-off energy $E_{cut-off}$. To study the changes of cluster- heads with their available energy, I have run the simulation for 3 minutes with 50 nodes and initial energy of each node is 50 Jules. Cluster-heads consume more energy compared to ordinary nodes and the gateway nodes because all data packets go through them. In this simulation, each packet size is considered 500 bytes and nodes are sending data to another nodes chosen randomly. During the simulation time I send different number of packets for different simulation run. I have considered a first order radio model.

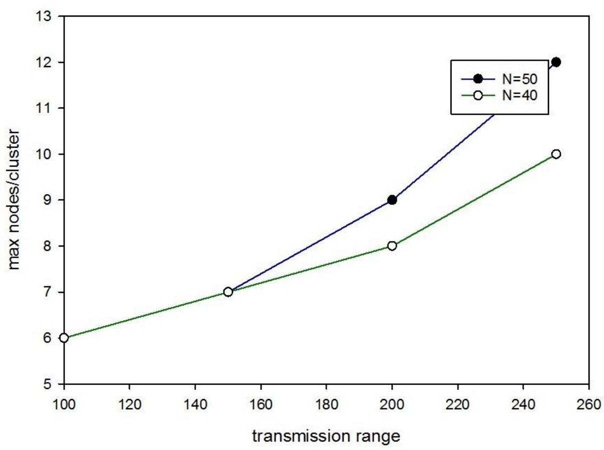

Fig. 5 Maximum number of nodes per cluster with different *R* for 50 and 40 nodes.

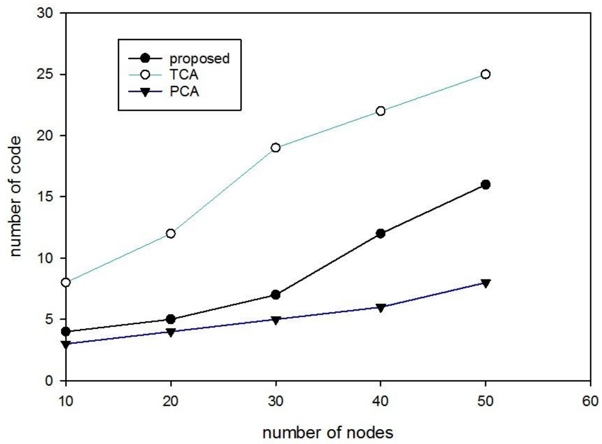

Fig. 6 Number of code with different node number for TCA, PCA and proposed system.

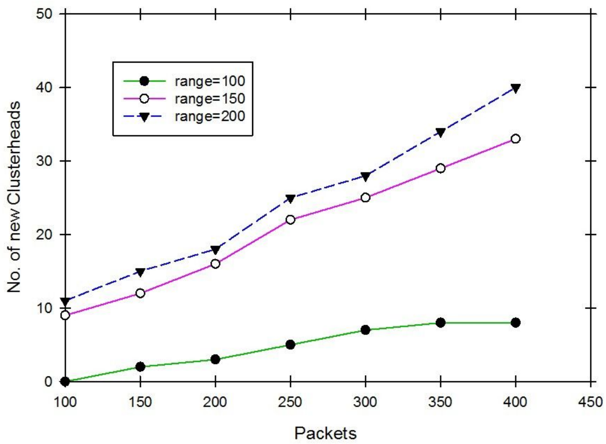

Fig. 7 Number of new cluster-heads with different load

In figure 7, it is shown that as the number of data packets increses which are sent by nodes in each clusters, decreases the available energy of the clusters and thus increases the need of new cluster formation. Similarly, when the transmission range increases, the cost of sending and receiving of data packets also increases. So the cluster-heads spend more energy with the rise of transmission range of the nodes. Thus, it makes the cluster-heads release their headship and becomes a nor- mal node of a newly elected cluster-head.

5. Conclusion

I have proposed two MAC protocols for wireless net- works. The first MAC protocol is based on CDMA which is implemented on wireless MANET networks. Assigning CDMA codes in highly dynamic ad hoc network is a very challenging and difficult problem. In this work, I have proposed to solve the problem of code assignment in ad hoc network. This work is used in the cluster-based ad hoc network to resolve both primary and secondary collision problem. Initially I have proposed an clustering algorithm followed by a code assignment algorithms. In the proposed code assignment algorithms, the CDMA codes are assigned to the cluster members by their respective cluster-heads in such a way that no collision occurs in future. I have shown that the code requirement of the network for the proposed system is lower than TCA but greater than the PCA which is also shown by the simulation. Though PCA needs lesser code than the proposed technique but its implementation is complex. I have also done simulation by incorporating the mobility of the nodes and the performances of the system is also shown in the result section.

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