A Novel Technique to Combat the Major Flaws for Broadcasting Protocols by Merging CDMA and OFDM in Wireless Ad-hoc Network

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Abstract— **In transmission from peer to peer wireless ad-hoc network, several customary algorithms such as probabilistic, counter, distance and location based schemes are being used as a method of broadcasting information from one node to another. These conventional algorithms are not capable of eradicating the data redundancy problem. This study proposes a new technique of merging the traditional algorithms to absolutely eradicate the data redundancy problem in such networks. However, the merging of counter and location based scheme with the distance based method can reduce the unnecessary re-transmission of information but it does not deal with the major flaws like contention and collision problems. The proposed technique also merges the Code Division Multiple Access (CDMA) and Orthogonal Frequency Division Multiplexing (OFDM) to address the aforementioned problems. Here, data is encrypted by using CDMA technique where each data is assigned an individual spreading code and these data bits are encoded with their respective codes. These encoded data signals are then multiplexed to form a CDMA signal and transmitted by using OFDM technique where several closely spaced orthogonal subcarriers are used to carry the signal. The proposed integration technique offers a significant improvement in data broadcasting in terms of collision, contention and security.**

Index Terms— **Broadcasting Protocols, Redundancy, Contention, Collision, CDMA, OFDM**

I. Introduction

In wireless networks two or more computer or network devices can communicate each other without any wired connection using standard protocols. An ad-hoc or peer-to-peer wireless network consists of a number of nodes, each equipped with a wireless networking interface card [1]. It can be easily constructed with low cost since wire line infrastructures need not to be installed.

Nodes in a mobile ad-hoc network are free to move and arrange themselves in a random manner. The path between each pair of nodes or users may have several links and the radio between them can be heterogeneous. Mobile ad-hoc networks can be used in some business atmosphere or it can also be used to provide crisis management services applications, as in disaster recovery, where the total communication infrastructure is demolished and restoring communication quickly is vital. By using a mobile ad-hoc network, an infrastructure could be set up in hours instead of weeks, as is required in the case of wired communication [2]

Broadcasting is a common mechanism to transmit the message in wireless ad-hoc network. It means spreading a message to all the nodes in the network. *Flooding is* traditionally used for broadcasting. According to this technique, every node sends the broadcasted message to its neighbors after receiving it for the first time. This approach is reliable, but as the probability of multiple requests at the same time for channel access becomes very high, it dramatically increases the number of collisions, and gives a lot of dropped packets as well as results in a high overload in the network [3]

Initially redundancy was the main flaw in wireless ad-hoc network which means unnecessary retransmission of data. Several algorithms including the probabilistic scheme, the counter based scheme, the distance and location based schemes were proposed to address the redundancy problem in flooding technique [4].These schemes were able to reduce the redundancy in the network but could not eliminate it completely [5]. From here merging concept came to address the redundancy. This merging concept of the conventional algorithms can provide the complete solution to the data overload problem but it cannot give the solution to remove contention and collision. [6]. Moreover, It cannot provide any data security and consumes a great amount of time for transmission [7]. In this new scheme, a novel model is proposed to merge the code division multiple access(CDMA) and orthogonal frequency division multiplexing (OFDM) techniques to address the aforementioned problems. Multi Carrier CDMA (MC-CDMA) spreads information from each data symbol over all tones of an OFDM symbol. At first glance, it is paradoxical to combine CDMA, which tries to spread a signal over a very large bandwidth, with multicarrier schemes, that try to signal over a very narrowband channel. However, the two methods can actually be combined very efficiently under certain circumstances. The uncoded OFDM has poor performance, because it is dominated by the high error rate of subcarriers that are in fading dips. Coding improves the situation, but in many cases a low coding rate – i.e., high redundancy is not desirable. By spreading a modulation symbol over many frequencies, MC-CDMA becomes less sensitive to fading on one specific frequency and thus exploits the frequency diversity of the channel.[8] The proposed method, however, avoids the MC-CDMA technique to avoid any contradiction; rather it uses the CDMA-OFDM technique where a CDMA signal is transmitted using different orthogonal subcarriers.

Originality of this work is-the integration of different multiplexing technique are uniquely conducted and likewise the performance analysis of the merged schemes in terms of major problems like redundancy, contention, collision, time consumption and data security is distinctively approached.

The paper is organized as follows. In Section II, the network model is briefly discussed. In Section III, Related works are reviewed in greater details. In Section IV, the merging techniques are proposed. In Section V, the performances of all merged techniques are analyzed and finally in section VI, conclusions are drawn.

II. RELATED WORKS

There are several schemes that deal with the reduction of the redundant rebroadcast and differentiate the timing of rebroadcast to compensate the broadcast storm. These schemes differ in how a host assesses redundancy and how it accumulates knowledge to assist its decision. These schemes are known as the probabilistic, counter based, distance based and location based scheme respectively. The probabilistic scheme is based on the probability based rebroadcasting. Here, a node rebroadcasts a message with a probability P on receiving the broadcast message for the first time. If the message received is already seen, then the node drops the message irrespective of whether or not the node retransmitted the message. But this scheme becomes equivalent to flooding if the value of P turns into 1 [9]. The counter based scheme comes up with a better solution in this regard. Here, the rebroadcasting of a node can be prevented when the expected additional coverage of the host's rebroadcast becomes too short. Specifically, a counter c is used to keep track of the number of times the broadcast message is received. A counter threshold C is chosen. Whenever $c \geq C$, the rebroadcast is inhibited. The distance based scheme uses the relative distance between nodes to make the rebroadcast decision instead of using a counter. A threshold distance is used as the reference value for the additional coverage area. If the relative distances of the nodes are small compared to the threshold, the retransmission is restrained to provide better reach-ability [4]. Otherwise, the received message is stored and the node initiates a Random Access Delay (RAD) timer. Redundant messages received before the expiry of the timer are also stored. When the RAD timer expires, the node calculates the distance between itself and the neighbor nodes that previously broadcast the particular message. If any such neighbor node is closer than the threshold distance, the message is dropped. Otherwise, it is transmitted [9]. The location based method is a revolutionary step to reduce the broadcast storm. In this case, the locations of the broadcasting nodes are determined to estimate the additional coverage more precisely. Whenever a node initiates or rebroadcasts a message, the node puts its location information in the message header. The receiver node calculates the additional coverage area that would be obtainable if it were to rebroadcast. If the additional coverage is less than a threshold value, all future receptions of the same message will be stopped. Otherwise, the RAD timer is started. Once the timer expires, the node considers all the reserved messages and recalculates the additional obtainable coverage area if it were to rebroadcast the particular message. If the additional obtainable coverage area is less than a threshold value, the reserved messages are dropped. Otherwise the message is rebroadcast. Such as GPS receivers. [10]

The performance analysis of the above method depicts that these methods behave like the flooding technique at some specific situations. The location based method has the best reach-ability and the best rebroadcast saving technique [4]. However, none of these schemes are able to stop the unnecessary rebroadcast of nodes completely. Then the merging concept came. The merging of the conventional counter and distance based methods, offers a high reach-ability and saves the number of rebroadcast compared to the individual counter or distance based methods. However, it is not much efficient in removing the redundancy. The merged distance and location based scheme appears as an excellent solution in this regard. This scheme provides a zero redundancy during the broadcast procedure. It decreases the number of rebroadcast in comparison to the first merged scheme yet offers an optimal reach-ability since it ensures that a complete inter-transmission among the nodes is held and the transmitted packet reaches its destination promptly. However none of these schemes are capable of solving the problems like contention, collision and data security. In this paper, CDMA and OFDM are integrated to come up with a solution to this problem.

III. NETWORK MODEL

The Network Model is fully decentralized type of wireless network concentrating on Omni directional network connectivity. The network is ad hoc because it does not rely on a pre-existing infrastructure. In this type of network connectivity every node is routing & forwarding data packets dynamically instead of single node in a particular centralized network.

In the proposed method, the code division multiple access (CDMA) and orthogonal frequency division multiplexing (OFDM) techniques are merged to address the redundancy, contention and collission problems. In this technique, several nodes are considered which would transmit and receive the data packets. Here, the data is encrypted by using the CDMA technique. An individual spreading code is assigned to each data and these data bits are multiplied with their respective codes. These multiplied data are added together to form a CDMA signal. The CDMA signal is then transmitted over the communication channel by using OFDM technique. The primary advantage of OFDM over single-carrier schemes is its ability to cope with severe channel conditions (for example, attenuation of high frequencies in a long copper wire, frequency selective fading due to multipath) without complex equalization filters. Channel equalization is simplified because OFDM may be viewed as using many slowly-modulated narrowband signals rather than one rapidly-modulated wideband signal. The low symbol rate makes the use of a guard interval between symbols affordable, making it possible to handle time-spreading and eliminate inter symbol interference (ISI).

From the experiment, the average transmitting time for single carrier and multiple orthogonal subcarrier transmission methods are compared in case of both single hop and multi hop (uses several intermediate nodes before destination) transmissions. It is observed that for both the cases, the average transmitting time is less for OFDM system which is a great advantage over the conventional single carrier method. The usage of CDMA and OFDM technique provides a solution for contention and collision problems. Contention problem arises when there is a very few number of channels available for a huge amount of separate data packets. Since in CDMA, all the separate signals are entangled together to form a single CDMA signal, the contention problem is mitigated. By using the OFDM technique, chances of having any collision are diminished as different mutually independent sub-carriers are used to transmit data. This paper proposes a novel idea for designing a protocol for the ad-hoc networks. The complete data analysis is done by using MS Excel. A network simulator could be implemented on the basis of this protocol which is an important future focus of this work.

IV. MERGED BROADCASTING TECHNIQUES

The previous works have demonstrated that the distance based method provides better reach-ability while it does not have much efficiency in saving the number of rebroadcast. On the other hand, the counter based scheme increases the number of saved rebroadcast and hence reduces redundancy but due to the usage of counter threshold, its reach-ability becomes poor. Here, at the first section, both of these schemes are merged to bring a balance between the reach-ability and transmission overhead.

A. Merged Counter and Distance Based Schemes

In this technique, firstly, some arbitrary broadcasting nodes are defined with their co-ordinate points which are shown in table I. Then the distances among all the nodes from each other are calculated. A distance threshold value is defined to help create the neighbor list of each node [5]. The sending and receiving nodes are defined then. According to this algorithm, initially, the neighbor lists of both of these nodes are determined. Then the sender broadcast the message to its neighbors. If the receiving node is present at the neighbor list of the sender, then it receives the sent packet at the first transmission and sends an acknowledgement to the sender. The sender then receives this acknowledgment and stops broadcasting. Therefore, it is seen that the single hop broadcasting is a very simple process. But, if the neighbor list of the sender does not contain the receiving node, the broadcasting becomes a multi-hop procedure. Here, a counter value (initially zero) is defined for all the nodes. After the first transmission from the sender, these counter values of the neighboring nodes are increased to 1. Then the distance of these nodes from the sender is measured by using the following formula.

$$\text{Distance, D} = \sqrt{(X_2\text{-}X_1)^2+(Y_2\text{-}Y_1)^2} \qquad (1)$$

Once all the distances are measured, they are compared and the node at the highest distance is found out [Fig 2]. This node is set to rebroadcast the packet. If the receiving node is present in the neighbor list of this highest distance node, then the sender receives an acknowledgement and halts broadcasting. Otherwise, the distance measurement process is held again and accordingly a second highest distance node rebroadcasts until the recipient node or its immediate neighbor is found. If the immediate neighboring node of the recipient is found in this process, then this node is set to rebroadcast the packet so that the receiving node acquires it and sends acknowledgment and eventually the broadcasting process comes to an end. In this process, the counter value of the non- receiving nodes are kept increasing at each of the re-transmission step to find out the number of redundant broadcast. The highest distant node is used for rebroadcast so as to achieve a better reach-ability. That's how a balance between both the conventional counter and distance based schemes is maintained and a better performance and reliability is achieved.

The following example illustrates this model in details. Using Microsoft Excel, different data for different nodes are considered and the broadcasting technique is analyzed according to this algorithm. 10 different nodes are used for the analysis. The following figure shows these nodes with their corresponding co-ordinates. The distance of the nodes from each other (shown in table II) is calculated by using the formula given by the equation 1. A threshold distance value of D=9 is set to find out the neighbor list of each node (shown in table III). The distance values found in figure 2 are compared to this threshold and any value greater than 9 is disregarded (set to zero) which means the nodes with a distance below the threshold is considered as the neighbor of the node from which the distance is being calculated.

Table I: Nodes with their co-ordinates

Node Name	A	B	C	D	E	F	G	H	I	J
X	5	-9	10	2	8	-5	1	6	7	4
Y	4	-5	6	0	7	3	-9	6	2	1

Table II : Distance among the nodes

DISTANCE BETWEEN EVERY 10 NODES										
Nodes	A	B	C	D	E	F	G	H	I	J
A	0	16.64331698	5.385164807	5	4.242640687	10.049876	13.60147051	2.236068	2.8284271	3.1622777
B	16.64331698	0	21.9544984	12.08304597	20.80865205	8.9442719	10.77032961	18.601075	17.464249	14.317821
C	5.385164807	21.9544984	0	10	2.236067977	15.297059	17.49285568	4	5	7.8102497
D	5	12.08304597	10	0	9.219544457	7.6157731	9.055385138	7.2111026	5.3851648	2.236068
E	4.242640687	20.80865205	2.236067977	9.219544457	0	13.601471	17.4642492	2.236068	5.0990195	7.2111026
F	10.04987562	8.94427191	15.29705854	7.615773106	13.60147051	0	13.41640786	11.401754	12.041595	9.2195445
G	13.60147051	10.77032961	17.49285568	9.055385138	17.4642492	13.416408	0	15.811388	12.529964	10.440307
H	2.236067977	18.60107524	4	7.211102551	2.236067977	11.401754	15.8113883	0	4.1231056	5.3851648
I	2.828427125	17.4642492	5	5.385164807	5.099019514	12.041595	12.52996409	4.1231056	0	3.1622777
J	3.16227766	14.31782106	7.810249676	2.236067977	7.211102551	9.2195445	10.44030651	5.3851648	3.1622777	0

Table. III: Distance among nodes after comparing with the threshold

DISTANCE COMPARISON (THRESHOLD = 9)										
Nodes	A	B	C	D	E	F	G	H	I	J
A	0	0	5.385164807	5	4.242640687	0	0	2.236068	2.8284271	3.1622777
B	0	0	0	0	0	8.9442719	0	0	0	0
C	5.385164807	0	0	0	2.236067977	0	0	4	5	7.8102497
D	5	0	0	0	0	7.6157731	0	7.2111026	5.3851648	2.236068
E	4.242640687	0	2.236067977	0	0	0	0	2.236068	5.0990195	7.2111026
F	0	8.94427191	0	7.615773106	0	0	0	0	0	0
G	0	0	0	0	0	0	0	0	0	0
H	2.236067977	0	4	7.211102551	2.236067977	0	0	0	4.1231056	5.3851648
I	2.828427125	0	5	5.385164807	5.099019514	0	0	4.1231056	0	3.1622777
J	3.16227766	0	7.810249676	2.236067977	7.211102551	0	0	5.3851648	3.1622777	0

Table. IV: Neighbor list of the nodes

Neighbor List										
Nodes	A	B	C	D	E	F	G	H	I	J
A	0	0	C	D	E	0	0	H	I	J
B	0	0	0	0	0	F	0	0	0	0
C	A	0	0	0	E	0	0	H	I	J
D	A	0	0	0	0	F	0	H	I	J
E	A	0	C	0	0	0	0	H	I	J
F	0	B	0	D	0	0	0	0	0	0
G	0	0	0	0	0	0	0	0	0	0
H	A	0	C	D	E	0	0	0	I	J
I	A	0	C	D	E	0	0	H	0	J
J	A	0	C	D	E	0	0	H	I	0

Table. V: Broadcasting procedure by using merged Counter and Distance based scheme

Sender	Receiver	No of rebroadcast	No of Redundancy	Counter
A	B			
B	F			
A	C,D,E,H,I,J		5	C,D E,H,I,J,=1
C	A,E,H,I,J	1	4	H,I,J,E=2
D	A,F,H,I,J	1	3	F=1,H,I,J=3
F	B	1	0	0
A-D-F	B			

Table IV depicts the neighbor list of each nodes determined on the basis of threshold value. From this figure it is evident that if any node of the first column is taken as the reference, its neighbor list consists of the nodes at its corresponding row. For example, neighbor list of B is F and similarly for D the list will be A, F, H & I.

Table V presents a scenario where the sending and receiving nodes are A and B respectively. At the first step, the neighbors of both the nodes are determined. From figure 4, it is found that the neighbors of sender A are C, D, E, H, I, J and the only neighbor of receiver B is F. According to this algorithm initially sender A broadcasts the packet to its neighbors. The neighbors receive the packet and increase their counter value to 1 since the recipient B is not present in A's neighbor list. Then for providing better reach ability the highest distant node from A among its neighbors is calculated. From Fig.3 it is apparent that C has the highest distance from A in comparison to D, E, H, I& J. Therefore C rebroadcasts the packet now to its neighbors and the initial broadcast to rest of the neighbors of A is considered as redundancy. So, the redundancy count is 5 in this case. . The neighbor list of C is found to be A, E, H, I, J. Since A is the sender, the counter values of rest of the nodes are increased to 2. Since the receiving node or its neighbor is not found at this stage, all the sent packets (except A) will be redundant in this step. Therefore the number of redundancy is 4 in this case. Hence, the second highest distant node D in sender A's neighbor list is determined and the same rebroadcast procedure is followed. At D's neighbor list, F is found which is eventually the neighbor of recipient B. Therefore the packets received by the rest of D's neighbors (except the sender A) will be redundant in this case with a redundancy count of 3. Now, node F is set to rebroadcast the process so that the recipient B can receive the packet. No redundancy is encountered here. Therefore, the final path from sender A to B is determined to be A-D-F-B.

B. Merged Distance and Location Based Schemes

The working process in this scheme is similar to the scheme discussed in the earlier section. Here as well, some arbitrary nodes are defined and the distance among these nodes are measured and the neighbor list is created using a distance threshold value. The main difference in this case is that, we don't use any counter value here. Instead, the location of the nodes is updated and track of their neighbors are kept. This neighbor list is continuously analyzed during the broadcast procedure until the recipient or its neighbor is found. Firstly, the neighbor list of the sender and receiver is determined. If at this stage, a common neighbor between them is obtained, the sender broadcasts the packet to this neighbor which rebroadcasts to its receiver. Otherwise, the sender's neighbor list is analyzed to determine the highest distant node from that. This node then determines its own neighbor list and check if the recipient or any of its neighbors is present in that list. If yes, the packet is broadcasted and sent to the recipient via its neighbor, else, a second highest distant node is found out and the procedure is repeated. It is notable that in this scheme, only recipient or its neighbor participate in the broadcast procedure since the packet transmission is held only when a route to the receiving node is obtained. In case of other nodes, the packet is blocked during broadcasting which enables this technique to absolutely eradicate redundant transmission while maintaining a high reach-ability.

Fig. 1 portrays two scenarios where C and B are the senders and D & C are the recipients in the 1st and 2nd scenarios respectively. The nodes and distances defined in table I, II and III are used in this scheme as well and consequently the same neighbor list of table IV is obtained.

Sender	Receiver	No of Rebroadcast	No of Redundancy
C	D		
C	A,E,H,I,J		
D	A,F,H,I,J		
C->J	D	1	0
B	C		
B	F		
C	A,E,H,I,J		
F	B,D		
D	A,F,H,I,J		
H	A,C,D,E,I,J		
B->F-D-H	C	3	0

Fig.1. Broadcast Procedure by merging of Distance and Location based scheme

According to these scheme, initially the neighbor list of sender C is determined which is found to be A, E, H, I, J. Then for the first scenario the neighbor list of receiver D is extracted which is A, F, H, I, J. This list is analyzed to check if the sender C or any of its neighbors is present there. Since there are 4 nodes (A, H, I, J) which are common between the sender and receiver, the distance of these neighbors from C are calculated. As J is the highest distant node in this case, C now sends the packet to J which then rebroadcast it to the receiver D. Here, the highest distant node is considered so that a high reach-ability of the packet could be obtained. That's how we obtain a transmission path from the sender C to the receiver D which is C-J-D. In case of all the other neighboring nodes of sender, C, the transmitted packets are blocked. Therefore, the number of redundancy is zero and since it uses only one node in between the sender and receiver, the number of rebroadcast is only one. The second scenario can also be illustrated in a similar fashion. Here, the neighbor list of Sender B and receiver C are extracted. Then node B's only neighbor F analyses its neighbor list (B, D) to check if C or any of its neighbor is present there. Since nothing is found, the neighbor list (A, F, H, I, J) of D is checked and B is ignored (since it is the initial sender). Here, some common nodes (A, H, I, J) with recipient C are obtained and hence the highest distant node from D is calculated. According to table III it can be seen that F is the longest distant node from D, but since this is already present in the path, a second highest distant node H is determined. As H is a neighbor of C, the broadcast path is obtained as B-F-D-H-C. This means the number of rebroadcast is 3 since there are three nodes in between the sender and recipient.

C. Merging of CDMA and OFDM Techniques

The schemes discussed so far are only to deal with the data redundancy problem and they are not able to provide any solution in handling collision in a contention based system. The aforementioned techniques are vulnerable even in terms of data safety. These observations prompt the idea of the merging scheme of different multiplexing and multiple access techniques (OFDM and CDMA).

In the proposed scheme, the same 10 nodes are considered here as well (depicted in table I). These nodes transmit and receive the data packets among each other. Here, the data is encrypted by using the CDMA technique. As mentioned earlier, an individual spreading code generated by a pseudo noise or pseudo random noise generator is assigned to each data and these data bits are multiplied with their respective codes. These multiplied data are multiplexed to form a CDMA signal which is transmitted over the communication channel. At the receiving end, only the destination node or receiver will have their respective pseudo code to extract the data packet by using a channel decoder. By these, the data security is ensured.

CDMA allows multiplexing technique where a single channel is occupied by multiple signals at the same time. Here communicating channel will be divided into several numbers of channels that adopt Orthogonal Frequency Division Multiplexing (OFDM) technique where each of the channels contains the CDMA encoded signal. OFDM technique is used to ensure higher data accessibility and to improve the quality of transmission and also it ensures maximum utilization of the medium. In case of mobility the nodes, the process will be repeated from the beginning and handover will be done in order to ensure that the current process is uninterrupted. The merging of CDMA and OFDM working procedures are given below:

For CDMA, for each of the single node is assigned the Device ID (shown in table VI). As for example for node A and B the ID's will be 0001 and 0010 respectively.

Table VI: Device ID of the each node

Device ID	Nodes
0001	A
0010	B
0011	C
0100	D
0101	E
0110	F
0111	G
1000	H
1001	I
1010	J

The CDMA codes have to be nearly orthogonal and the cross- correlation of any of these two codes have to be zero, they must be pseudorandom in nature and the dot product of a code scaled by the order of the code must be equal to 1. For forming a simple CDMA signal a spreading code of order 4 is chosen. Two data signals are chosen such as:

M1 (t) = +1-1+1

M2 (t) = +1+1-1

Signal 1 has spreading code: C1 (t) = -1-1+1+1

Signal 2 has spreading code: C2 (t) = -1+1+1-1

The following steps illustrate the procedure of forming a CDMA signal which is shown in fig. 2.

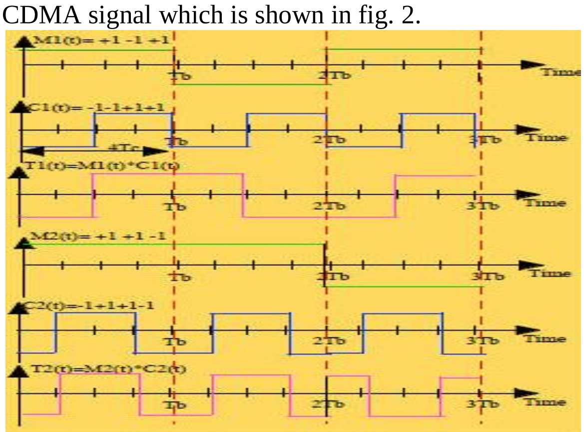

Fig. 2.Steps to form a simple CDMA signal

According to the CDMA principle, for a data bit of 1, the spreading code itself is transmitted whereas for data bit of 0 the code is inverted. Initially the data signal M1(t) is multiplied with the spreading code C1(t) for encoding the data. Here, the time period of each bits of signal M1(t) is T_b. The complete 4bit spreading code is multiplied with each of the individual bits of the data signal to provide a output of [T1(t) = M1(t)*C1(t)]. Same procedure is applied for signal M2(t) where it is encoded with C2(t) to come up with a output of [T2(t) = M2(t)*C2(t)]. These encoded signals T1(t) and T2 (t) are then added together to obtain the desired CDMA signal [S(t) = T1(t) + T2(t)].

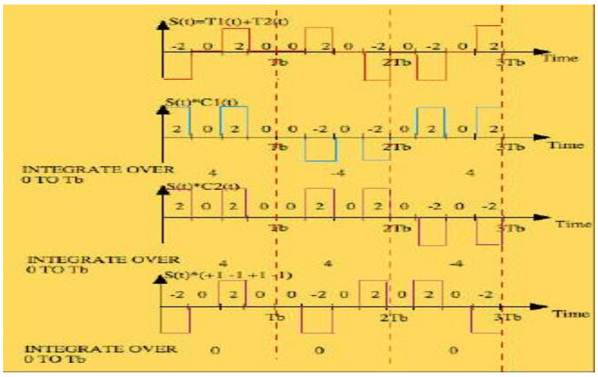

Fig.3. Decoding steps at the receiving end

The individual data packets are then extracted from this signal by using de-encryption method. The decoding steps at the receiving end are shown in fig. 3.

To obtain the first data signal M1(t), the CDMA signal S(t) is multiplied with the spreading code C1(t) of that signal. The resulting outputs of [S(t)*C1(t)] are integrated over 0 to T_b to obtain a signaling sequence of +4 -4 +4. By dividing these by the order of the spreading code, 4, the first data signal M1(t) is obtained where, M1(t) =+1 -1 +1. Similarly, the second data signal M2(t) is obtained by multiplying the CDMA signal S(t) with the second spreading code C2(t) and integrating the resulting outputs over the total time period T_b and dividing by the spreading code order. In the last part of figure 8 the data security of CDMA is depicted. Here, instead of C1(t) and C2(t), the CDMA signal is multiplied by an arbitrary random spreading code +1-1+1-1. The integrated resulting outputs of this operation end up in an outcome of 0 0 0. This indicates that if an intruder spreading code is used to extract the information, a sequence of zero is obtained instead of the original bits. Therefore, the information security is ensured.

The CDMA signal is transmitted in two different ways. The 1st method uses a single carrier to transmit the signal whereas we use OFDM technique in the 2nd method. Here, the signal is transmitted by using 5 closely spaced orthogonal subcarriers. The CDMA signal is divided into several parallel data streams, one for each sub-carrier which is modulated with a conventional modulation scheme (such as Quadrature Amplitude Modulation or Phase Shift Keying). The symbol rates of the data streams are kept low and it is ensured that the total data rate is equal to the data rate of conventional single carrier transmission method. [6] After passing through the OFDM transmitter block, the CDMA signal is received at the receiving end. As mentioned earlier, the individual data packets are then extracted from this signal by using the de-encryption method.

Now, for previously used 10 nodes, from table III, the time between two nodes is measured by the following formula and the time measurement table is formulated in figure 9.

$$s = vt \qquad (2)$$

Where, s = distance between two nodes

t = Required time

v = Velocity of light = 3x10^8 m/s

Table VII. Time measurement table

Nodes	A	B	C	D	E	F	G	H	I	J	Avg Time
A	0	0	0	0	0	0	0	7.4536E-09	9.42809E-09	1.0541E-08	7.61819E-09
B	0	0	0	0	0	0	0	0	0	0	2.98142E-09
C	1.7951E-08	0	0	0	0	0	0	1.3333E-08	1.66667E-08	2.6034E-08	8.14383E-09
D	1.6667E-08	0	0	0	0	0	0	2.4037E-08	1.79505E-08	7.4536E-09	9.14937E-09
E	1.4142E-08	0	0	0	0	0	0	7.4536E-09	1.69967E-08	2.4037E-08	7.0083E-09
F	0	2.9814E-08	0	0	0	0	0	0	0	0	5.52002E-09
G	0	0	0	0	0	0	0	0	0	0	0
H	7.4536E-09	0	0	0	0	0	0	0	1.37437E-08	1.7951E-08	8.39717E-09
I	9.4281E-09	0	0	0	0	0	0	1.3744E-08	0	1.0541E-08	8.53266E-09
J	1.0541E-08	0	0	0	0	0	0	1.7951E-08	1.05409E-08	0	9.65571E-09

From table VII, it can be seen that for each and every single node, average time is also calculated by adding all the individual time required between two nodes which is then divided by the total number of neighbors.

Table VIII. Round Trip Time Table

Nodes	A	B	C	D	E	F	G	H	I	J	Avg Time
A	0	0	3.59E-08	3.33E-08	2.82843E-08	0	0	1.49071E-08	1.8856E-08	2.1082E-08	1.52364E-08
B	0	0	0	0	0	5.963E-08	0	0	0	0	5.96285E-09
C	3.59E-08	0	0	0	1.49071E-08	0	0	2.66667E-08	3.3333E-08	5.2068E-08	1.62877E-08
D	3.333E-08	0	0	0	0	5.077E-08	0	4.8074E-08	3.5901E-08	1.4907E-08	1.82987E-08
E	2.828E-08	0	1.491E-08	0	0	0	0	1.49071E-08	3.3993E-08	4.8074E-08	1.40166E-08
F	0	5.963E-08	0	5.08E-08	0	0	0	0	0	0	1.104E-08
G	0	0	0	0	0	0	0	0	0	0	0
H	1.491E-08	0	2.667E-08	4.81E-08	1.49071E-08	0	0	0	2.7487E-08	3.5901E-08	1.67943E-08
I	1.886E-08	0	3.333E-08	3.59E-08	3.39935E-08	0	0	2.74874E-08	0	2.1082E-08	1.70653E-08
J	2.108E-08	0	5.207E-08	1.49E-08	4.8074E-08	0	0	3.59011E-08	2.1082E-08	0	1.93114E-08

For complete transmission of a single packet within a network, it is also necessary to consider the acknowledgement time along with travel time from a specific source to a specific destination [11]. Therefore, The Round Trip Time is calculated for every node by doubling the individual required time and then get the average Round Trip Time. The round trip time table is shown in table VIII. Thereafter, the two scenarios (single hop and multi hop) are represented and data is manually analyzed to demonstrate the merged CDMA-OFDM technique.

For a single transmission from the source to destination node, the total data size is assumed to be 1000 Megabit (Mb) and the size of each of the packet is assumed to be 10 Mb. Therefore, for a single channel transmission, the number of packets will be 100 whereas for transmission using 5 orthogonal subcarriers (channels), the packet number will be 20 for each of the subcarriers. According to the definition of OFDM, the date rate is assumed as 20 Mbps for both single and multicarrier transmission. However, the symbol rate of each of the subcarriers is kept low than that of the single carrier. For a single channel transmission using 64 QAM modulation techniques, the symbol rate is obtained as 3.333 Mbps by using the following formula-

$$R = f_s \log_2 M \qquad (3) \ [12]$$

Here, R = Bit rate = 20 Mbps

f_s = Symbol rate = 3.333 Mbps

M = 64 (for 64 QAM)

Now, for the multicarrier system using 5 channels, the OFDM symbol rate (Of_s) is calculated by dividing the total symbol rate by the number of channels which is found to be 0.667 Mbps. Hence, the OFDM subcarrier bit rate (OR) is calculated by using the same formula depicted by equation (3) which is obtained as 4 Mbps. This in turn gives a total data rate of 20 Mbps for the OFDM system and eventually demonstrates that though the data rate is same for both the single and multicarrier system, the symbol rate is much lower for OFDM.

After addressing the theoretical definitions the single and multi hop scenario is illustrated in table IX and X respectively.

Table IX. Single hop scenario

Single Hop								
Single Hop (10 NODES)					Total Transmitting Time		Average Total Transmitting Time	
Sender	Receiver	No of Rebroadcast	No of Redundancy	RTT	Single Channel	5 Channel	Single Channel	5 Channel
A	C	0	0	3.59011E-08	3.59011E-06	7.1802E-07	2.5394E-06	5.0788E-07
	D	0	0	3.33333E-08	3.33333E-06	6.6667E-07		
	E	0	0	2.82843E-08	2.82843E-06	5.6569E-07		
	H	0	0	1.49071E-08	1.49071E-06	2.9814E-07		
	I	0	0	1.88562E-08	1.88562E-06	3.7712E-07		
	J	0	0	2.10819E-08	2.10819E-06	4.2164E-07		

Table IX presents a set-up where the sender is A and the receivers are C,D,E,H,I and J. Since there is no intermediate node in between the sender and receiver, no rebroadcast will occur here. The number of redundancy will also be zero since the use of CDMA will enforce the redundant nodes to be automatically pruned. Thereafter, from figure 10, the round trip times for all the receivers are considered. For example, for the receiver C round trip time is 3.59011E-08s. The total transmitting time for single channel transmission can be acquired by multiplying the round trip time with 100 since the number of packet is 100 in this case. Accordingly, since for OFDM, the number of packet is 20 for each of the 5 subcarriers, the transmission time for five channels can be obtained by multiplying the round trip time with 20. As each of the subcarriers transmit in a parallel manner at the same time, this technique consumes much less time compared to the time required for the single channel transmission. The same procedure is followed to calculate the transmitting time for the other receivers as well and finally, taking the average, the single and five channels average trasmission times are obtained that are 2.5394E-06s and 5.0788E-07s respectively which demonstrates the much better efficiency of OFDM technique.

Table X. Multihop scenario

	Sender	Receiver	No of Rebroadcast	No of Redundancy	RTT		Single Channel	5 Channel
Aim	A	B						
Neighbor	B	F						
Neighbor	A	C,D,E,H,I,J						
A	C	A,E,H,I,J						
	D	A,F,H,I,J						
	E	A,C,H,I,J						
	H	A,C,D,E,I,J						
	I	A,C,D,E,H,J						
	J	A,C,D,E,H,I				Transmitting Time	1.43734E-07	
Transmtting Path	A	D-F-B	2	0	1.43734E-07	Total Transmitting Time	1.43734E-05	2.8747E-06

In table X, a multihop scenario for sender A and receiver B is portrayed. At the first step, the neighbors of both the nodes are determined. From figure 4, it is found that the neighbors of sender A are C, D, E, H, I, J and the only neighbor of receiver B is F. Then the optimum transmitting path A-D-F-B is obtained by using the same algorithm that was used in merged distance and location based scheme. This means the number of rebroadcast is 2 since there are two nodes in between the sender and recipient. However, CDMA ensures that there is no redundancy as the sent packet is encapsulated by the unique spreading codes that are intended only for the nodes present at the transmission path. This path also provides the optimum round trip time which is 1.43734E-07s. Hence, the total transmission time is obtained for single (1.43734E-05s) and five channels (2.8747E-06s) for the multi hop scenario by following the same procedure of single hop. These values clearly depict that it requires much less time for the multicarrier transmission system in case of multi hop state too.

V. PERFORMANCE ANALYSIS

This section evaluates the performance of the proposed scheme. Fig. 4 shows the position of the node described in table I. For all the schemes the same nodes are used. Two scenarios are considered here where in single hop, recipient node is found in the sender's neighbor list and for the multihop case, recipient is absent in the sender's neighbor list. So untill recipient is found, the packet need to broadcasted.

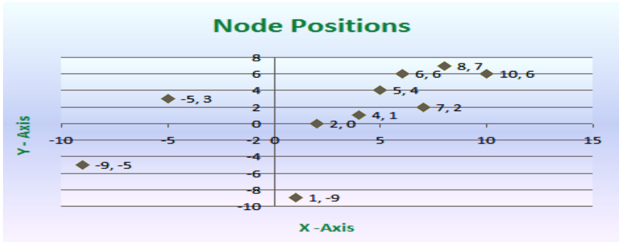

Fig. 4. Node positions

A. *Merging of Counter and Distance Based Schemes*

For the performance analysis of this scheme, firstly, the algorithm is investigated with 10 different nodes. The main target of the Analysis is to find out the transmission path of each of the nodes from the others. For example, if node A is set as the sender, then the analysis procedure determines each of its transmission paths to the other 9 nodes. This way, the paths for all the 10 nodes are found out. In this process, the route using single hop might be found or multi hops might be encountered. In case of multi hops the nodes need to rebroadcast the information packet. For this analysis using 10 nodes, the total number of rebroadcast is found to be 77 and the number of redundancy to be 320. Then the same is determined for 3, 5 and 7 nodes using MS Excel functions (on the basis of the algorithm) and eventually the following table is obtained. [13]

Table. XI

Number of Nodes	3	5	7	10
Number of Rebroadcast	0	8	48	77
Number of Redundancy	0	9	54	320

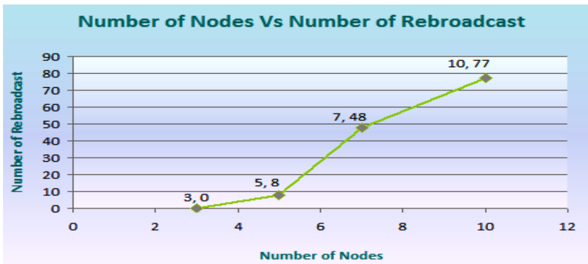

Fig. 5. Rebroadcast characteristics of merged Counter and Distance based schemes

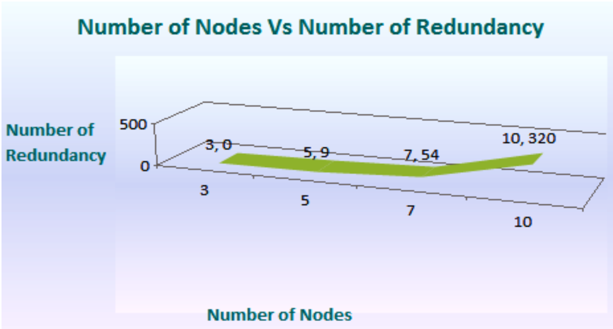

Fig. 6. Redundant characteristics of merged Counter and Distance based schemes

Fig. 5 and 6 shows the number of rebroadcast and redundancy in terms of number of nodes. From fig. 5 it is evident that the number of rebroadcast increases for increasing the number of nodes. Higher number of rebroadcast suggests that we get a better reach-ability by merging the counter and distance based schemes. However, fig. 6 depicts that though a better reach-ability is achieved by using this technique, the redundant packet transmission cannot be removed completely. In this case, the use of the counter helps to keep track of the redundant packets.

B. Merging of Distance and Location Based Schemes

The same procedure is followed for the performance evaluation of this scheme as well. The scenario is analyzed for 3, 5, 7 and 10 nodes in this case too. But from table III it can be observed that the number of rebroadcast is quite less here in comparison to the earlier scheme. Also, no redundancy is encountered in this case which is the most significant improvement. This is because, here, the broadcast procedure is initiated only after the transmission path is obtained by using the neighbor list of the sender.

Table. XII

Number of Nodes	3	5	7	10
Number of Rebroadcast	2	3	33	57
Number of Redundancy	0	0	0	0

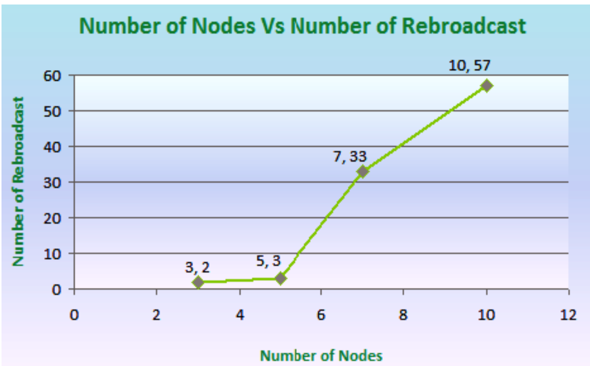

Fig. 7. Rebroadcast characteristics of merged Distance and Location based schemes

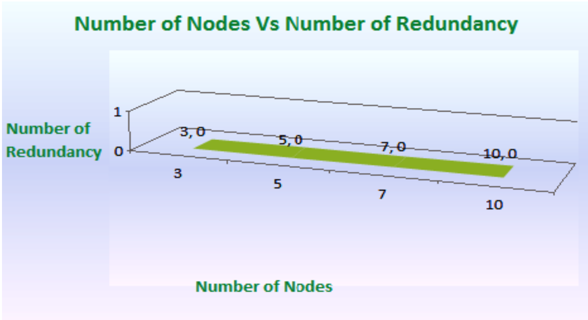

Fig. 8. Redundant characteristics of merged Distance and Location based schemes

Fig. 7 shows a significant reduction in the number of rebroadcast in comparison to the number illustrated in fig. 5. In case of merged distance and location based scheme, for the analysis of 5 nodes, the number of rebroadcast is found to be 3 whereas for the merged counter and distance based scheme, the rebroadcast count is 8. Similarly, for 10 nodes the number of rebroadcast is 57 and 77 for the merged distance and location based scheme and merged counter and distance based scheme respectively. This means that the former scheme provides a better reach-ability with prompt transmission from sender to receiver while maintaining a minimum number of rebroadcast.

From the comparison of fig. 6 and 8 also, it can be deduced that the merged distance and location based scheme is a much better technique for packet broadcasting as it offers zero redundancy for any number of nodes. From fig. 6, it is seen that as the number of nodes is increased, the number of redundancy also increases and for the case of 10 nodes, the number of redundant packets go as high as 320 whereas for fig. 8, the corresponding value is zero which means no redundant packet transmission. But both of these schemes are incapable to solve contention and collision problem. Also in terms of authentication of the data, it cannot give the solution.

C. Merging of CDMA and OFDM Technique

This technique is mainly used to provide a solution for the collision and contention since OFDM provides a means for the data packets to be sent on orthogonal sub-carriers which are independent of one another. The CDMA technique ensures the authenticity by means of the unique pseudo code. This merged technique also provides the lowest number of rebroadcast with zero redundancy. For the performance analysis of this technique, the same sets of nodes are used as in earlier cases.

Table. XIII

Number of Nodes	3	5	7	10
Number of Rebroadcast	0	4	31	54
Number of Redundancy	0	0	0	0

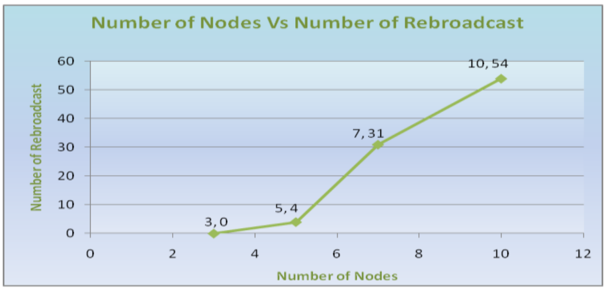

Fig. 9. Rebroadcast characteristics of merged CDMA and OFDM

From fig. 7 and 9, it is apparent that in terms of total number of rebroadcast, the performance of the merged CDMA-OFDM technique is almost similar to that of the merged distance and location based scheme for the same set of nodes. This is due to the fact that the same algorithm is used for both the cases to find the optimum transmission path. However, the number of retransmission is slightly less in case of CDMA-OFDM. The analysis of fig. 10 shows that the redundancy is zero for all set of nodes. Therefore, in terms of number rebroadcast and redundancy this is clearly the best scheme.

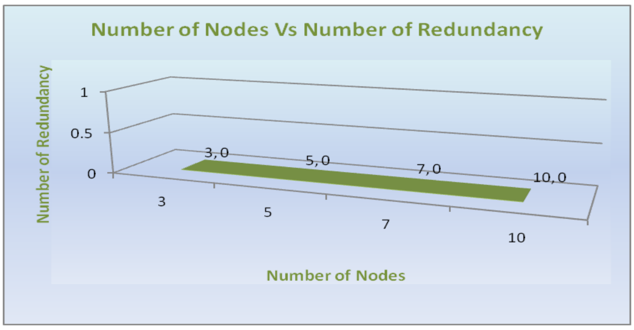

Fig. 10. Redundant characteristics of merged CDMA and OFDM

The average transmitting time for single carrier and multiple orthogonal subcarrier transmission methods are compared in case of both single hop and multi hop transmissions in the fig. 11 and 12. Table *XIV* and *XV* show the average total transmitting time for single hop and multi hop respectively. From table *XIV*, it is seen that for node A, average total transmitting time for single channel is 2.5394E-06s where as for five channels total average transmitting time is 5.0788E-07s which is quite less. Similarly, for the rest of the nodes (B, C, D, E, F, G, H, I, J) in single hop scenario, the average total transmitting time for single channel is quite higher than that of multi channel (five channel) system.

Table.XIV

SINGLE HOP		
COMPARISON OF AVERAGE TOTAL TRANSMITTING TIME		
Nodes	Single Channel	5 Channel
A	2.5394E-06	5.0788E-07
B	5.96285E-06	1.19257E-06
C	3.25753E-06	6.51506E-07
D	3.65975E-06	7.3195E-07
E	2.80332E-06	5.60664E-07
F	5.52002E-06	1.104E-06
G	0	0
H	2.79906E-06	5.59811E-07
I	2.84422E-06	5.68844E-07
J	3.21857E-06	6.43714E-07

In case of multi hop scenario depicted in table *XV*, the average total transmitting time for five channels is found to be less compared to the single channel which is the same as single hop. As for example, for node A, the average time is 1.13919E-05s for single channel whereas it is 2.27839E-06s for five orthogonal sub channels. Likewise, for node D single channel average total transmitting time is 3.65975E-06s while for five channels the time is 7.3195E-07s. This easily demonstrates that by using parallel orthogonal sub channels the same amount of data can be transmitted at a much faster rate. Since the data rate for each of the parallel sub carriers are kept equal to that of the single carrier, they transmit more number of packets at the same time. This in turn gives the overall faster data rate.

Table.XV

MULTI HOP		
COMPARISON OF AVERAGE TOTAL TRANSMITTING TIME		
Nodes	Single Channel	5 Channel
A	1.13919E-05	2.27839E-06
B	1.51236E-05	3.02472E-06
C	1.20699E-05	2.41399E-06
D	7.96645E-06	1.59329E-06
E	1.15342E-05	2.30683E-06
F	9.42399E-06	1.8848E-06
G	0	0
H	1.22618E-05	2.45235E-06
I	1.16487E-05	2.32974E-06
J	9.54932E-06	1.90986E-06

Figure 11 and 12 illustrate these comparison graph for single hop and multihop scenarios respectively for both single and five channels.

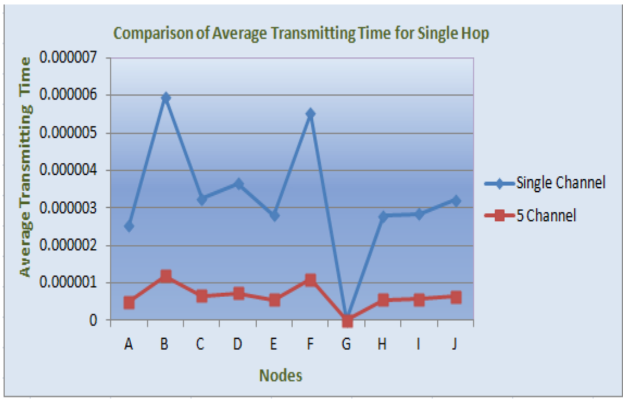

Fig.11. Comparison of Average Total Transmitting Time for Single Hop

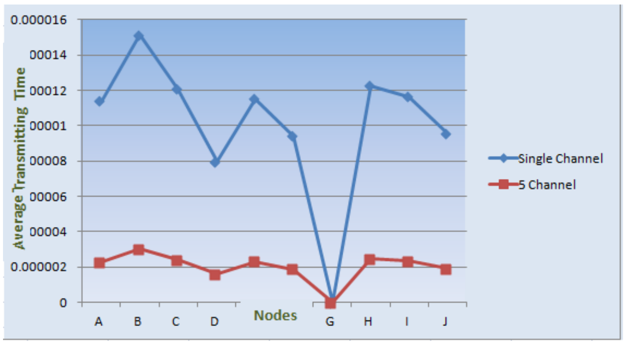

Fig. 12. Comparison of Average Total Transmitting Time for Multi Hop

VI. CONCLUSION

This paper mainly focuses on the improvement of performance of the broadcast techniques to provide immunity to redundancy and an optimum level of reach-ability. The first scheme that merged the conventional counter and distance based methods, offers a high reach-ability and saves the number of rebroadcast compared to the individual counter or distance based methods. However, it is not much efficient in removing the redundancy. The analysis shows that the merged distance and location based scheme appears as an excellent solution in this regard. This scheme provides a zero redundancy during the broadcast procedure. It decreases the number of rebroadcast in comparison to the first scheme yet offers an optimal reach-ability since it ensures that a complete inter-transmission among the nodes is held and the transmitted packet reaches its destination promptly. The merged CDMA-OFDM technique brings further development into the packet broadcast process. It not only ensures the lowest rebroadcast and redundancy, but also provides security through a unique authentication process. This also addresses the contention and collision problems which are the burning issues for the ad-hoc wireless networks. The use of OFDM ensures a much lesser average transmitting time which is a great advantage over the conventional single carrier method.

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