# OPTIMIZATION OF NODES IN MIXED NETWORK USING THREE DISTANCE MEASURES

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## ABSTRACT

This paper presents a method for the management of mixed networks as envisioned in future iNET applications and develops a scheme for global optimal performance for features that include signal to Noise Ratio (SNR), Quality of service (QoS), and Interference. This scheme demonstrates potential for significant enhancement of performance for dense traffic environments envisioned in future telemetry applications.

Previous research conducted at Morgan State University has proposed a cellular and Ad hoc mixed network for optimum capacity and coverage using two distance measures: QoS and SNR. This paper adds another performance improvement technique, interference, as a third distance measure using an analytical approach and using extensive simulation with MATLAB. This paper also addresses solutions where performance parameters are correlated and uncorrelated. The simulations show the optimization of mixed network nodes using distance, traffic and interference measures all at one time. This has great potential in mobile communication and iNET.

## KEY WORDS

Mixed Network, Ad hoc, Clustering, QoS, Interference Management

## 1. INTRODUCTION

The integrated Network Enhanced Telemetry effort (iNET) was launched to generate a telemetry network that will enhance the traditional IRIG-106 point-to-point telemetry link from test articles (TAs) to ground stations (GS). Research conducted at Morgan State University (MSU) has focused on providing solutions for two important critical needs identified by the Central Test and Evaluation Investment Program (CTEIP). They are: “the need to be able to provide reliable coverage in potentially high capacity environments, even in Over-The-Horizon (OTH) settings”, and “the need to make more efficient use of spectrum resources through dynamic sharing of said resources, based on instantaneous demand thereof”.

The Mixed Network architecture developed by MSU has shown that a cellular-Adhoc hybrid network can be used to provide coverage for TAs that are beyond the coverage area of the GS, while maintaining the desired level of QOS for all TAs in the network. Mixed network uses clustering techniques to partition the aggregate network into clusters or sub-networks based on properties of each TA, which currently include signal to noise ratio, QoS and Interference in [1] [2]. The paper starts with an overview of the mixed network architecture followed by the addition of three distortion measures that affects the performance of each sub-network: Location (SNR), traffic (QoS) and Interference. Finally, a discussion of new distance measure: Interference, performance improvement technique, using an analytical approach and using extensive simulation with MATLAB is presented.

## 2. MIXED NETWORK ARCHITECTURE

Cellular technology provides a high capacity network with spectral efficiency but with coverage that is limited as a function of the transmitted power and path loss exponent [3]. By contrast Mobile Adhoc network (MANET) technology operates with no centralized control mechanism; and provides high coverage but with diminished capacity. Mixing of these two technologies are demonstrated by [1] for optimal coverage and capacity. The proposed mixed network architecture by MSU is illustrated in Figure 1 and uses an optimized clustering scheme based on distance and angle developed by [1] to divide nodes into cellular nodes (within the coverage area of the Ground Station(GS)) and one or more ad-hoc sub networks also known as cluster cells(CC) shown in figure1. The word nodes and TAs are used interchangeably for the rest of this paper to refer to wireless terminals. All TAs are equipped with dual interface Network Interface Cards (NIC) that allows them to operate in cellular mode (CM), ad-hoc mode (AHM) or gateway mode (GM) depending on their location from the GS. The nodes in the Ad hoc network communicate in multi-hop fashion and they dynamically route their own traffic using standard routing protocols like DSDV, DSR, and AODV. The performance of the Ad hoc network is affected by two parameters: Contention and Queuing. Contention is one of the main factors that weigh in for creating the cluster cells. Contention is essentially competition among the nodes to have their data transmitted to their respective destinations among common routes. Gateway nodes (GN) are capable of communicating in both cellular and ad hoc mode simultaneously and they can be used to relay data from TAs that are operating in OTH settings to the GS or vice versa. Queuing exists at the gateway nodes; the TAs will be in the Queue at the gateway node. Every node can become a gateway node depending on its configuration. More information regarding the architecture of the mixed network and the basic clustering scheme can be found in [1] [4].

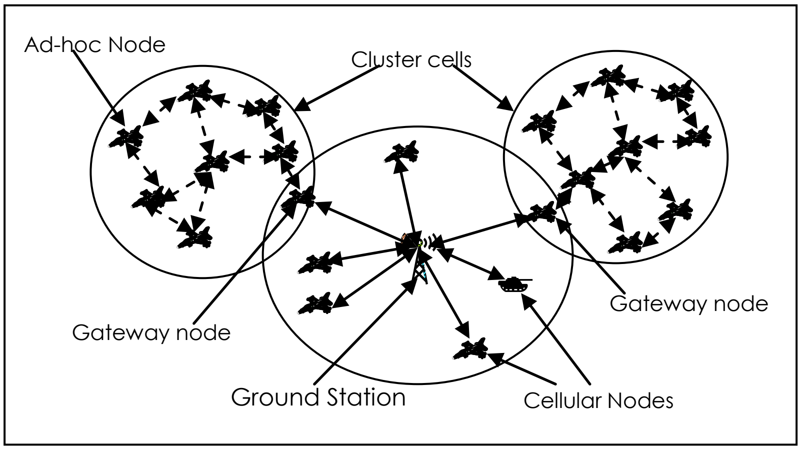


Figure 1: Mixed Network Architecture (source [1])

## 3. CHOICE OF DISTORTION MEASURE FOR CLUSTERING

The use of clustering for organizing nodes in mixed network offers several advantages. It improves manageability, increases throughput, reduces overhead and minimizes network congestion among other advantages [1]. Choosing clustering methods are a good way to improve the network quality; MSU proposes three distance measures to cluster Adhoc nodes for global optimal node distribution. These measures are:

3.1) distance (SNR) measure

The first step to cluster nodes is based on SNR value to GS, A threshold value is set for the SNR and any node with SNR greater than the threshold value is considered a CM node and those with SNR less than the threshold value are considered as AHM node. Nodes with shortest distance to centroid are grouped in the same cluster cell. In this measure the only way to cluster nodes into the same group is the physical location to the centroid. This measure is used for network continuity between Adhoc nodes.

3.2) Traffic (QoS) measure

Distance measure for SNR is not the only measure for clustering nodes; it doesn't uniformly adjust traffic distribution per cluster, this can lead to congestion and poor QoS. So traffic management is very important in a mixed network in order to provide QoS guarantees to the different users. We assume that nodes that are located in the ad-hoc sub-network are randomly generating traffic. In order for our mixed network to provide QoS guarantees for the nodes, it has to assure that the traffic level among nodes in each CC is distributed based on optimized traffic and an SNR distance measure of the nodes. This will be one of the key requirements of the enhanced clustering algorithm.

3.3) Interference measure

Another important parameter that affects the performance of the mixed network is the interference power ratio that is generated by TAs from co-channel clusters and adjacent clusters. The Interference environment can be categorized into two groups. One is referred to the additive types of interference, which include co-channel, adjacent channel, intersystem intermodulation, and intersymbol interference. The other is referred to as the multiplicative type, which is mainly the effect of multipath reflections, diffraction, and dispersion of transmitted signals as they enter the receiver of wireless systems. For the purpose of this study we assume that opposite clusters are operating with the same frequencies, TAs of one cluster act as interferers to TAs in the opposite cluster. When adjacent channel interference is compared with co-channel interference at the same level of interfering power, the effects of the adjacent channel interference are always less [5].

The signal to Interference Ratio (SIR) for standard mobile wireless system can be approximated by [5]

$$\frac{S}{I} = \frac{1}{M} \cdot \left(\frac{D}{R}\right)^n \quad (1)$$

Where: M = the number of co-channel interfering clusters;
n= path loss exponent; D = distance between two co-channel clusters; R = radius of a cluster.

In this analysis, we assume that we are using an Orthogonal Frequency Division Multiplexing (OFDM) signal that was developed for an aeronautical channel in [6]. The basic equation for the SIR of a TA and a carrier for an OFDM system in the case of synchronously arriving signals is:

$$(SIR)_i = \frac{P_{iR} G_p}{\sum_{\substack{j=0 \\ j\neq 1}}^{N} a_j \cdot P_{jR} + \sum_{k=0}^{M} \beta_{IC} \cdot P_{kR}^{tot} + N_o} \quad (2)$$

Where $P_{iR}$= the receiver power of the carrier $i$; $P_{kR}^{tot}$= the total received power from Gateway transceiver station $k$; $G_p$= the processing gain; $a_j$= the orthogonality factor for intra-cluster interference; $\beta_{IC}$= models the orthogonality loss due to non-ideal channel estimation and due to fading multipath channel; $N_o$= models the thermal noise.

This interference management function is useful in re-clustering the mixed network structure. Now, the clusters will be characterized based on the distance, traffic and interference measure.

## 4. IMPLEMENTING THREE DISTORTION MEASURE IN THE ENHANCED CLUSTERING ALGORITHM

The original clustering algorithm presented in [1] is based on two stage "k-means" clustering scheme. The first stage is classifying nodes into either cellular or ad-hoc network based on their location from the GS. This is accomplished by computing their SNR using their distance from the GS and set threshold value, if the node is greater than the threshold value, cluster nodes to cellular network and else cluster nodes to Ad-hoc network. It is shown in figure 2.

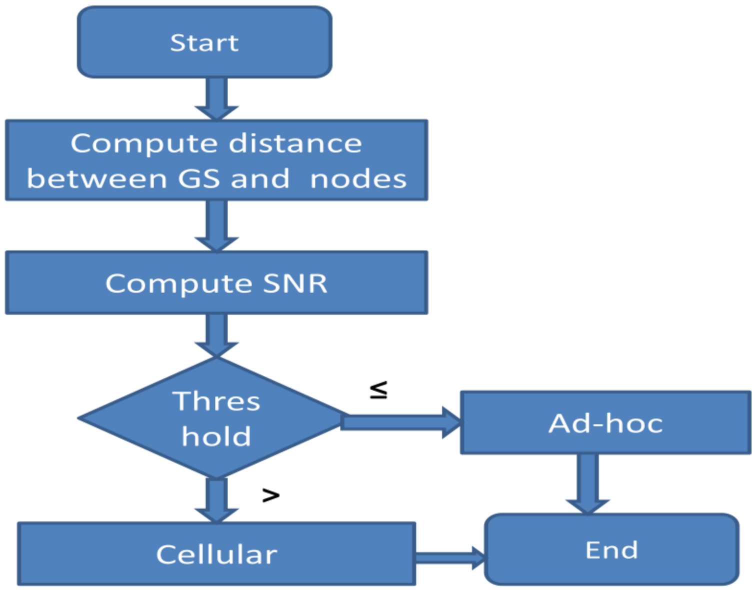


Figure 2: Classification of Nodes, Stage one

In the second stage shown in figure 3, the enhanced algorithm groups the ad-hoc nodes into k clusters cells; based on the minimum distance between each node and k-centroids, uniformly distributed traffic between each cluster and less interference between co-channel clusters. Although the k-centroids are initially set to some point in the xy axis, the algorithm converges when the location of the k-centroids doesn't change anymore indicating that they have reached their optimum position.

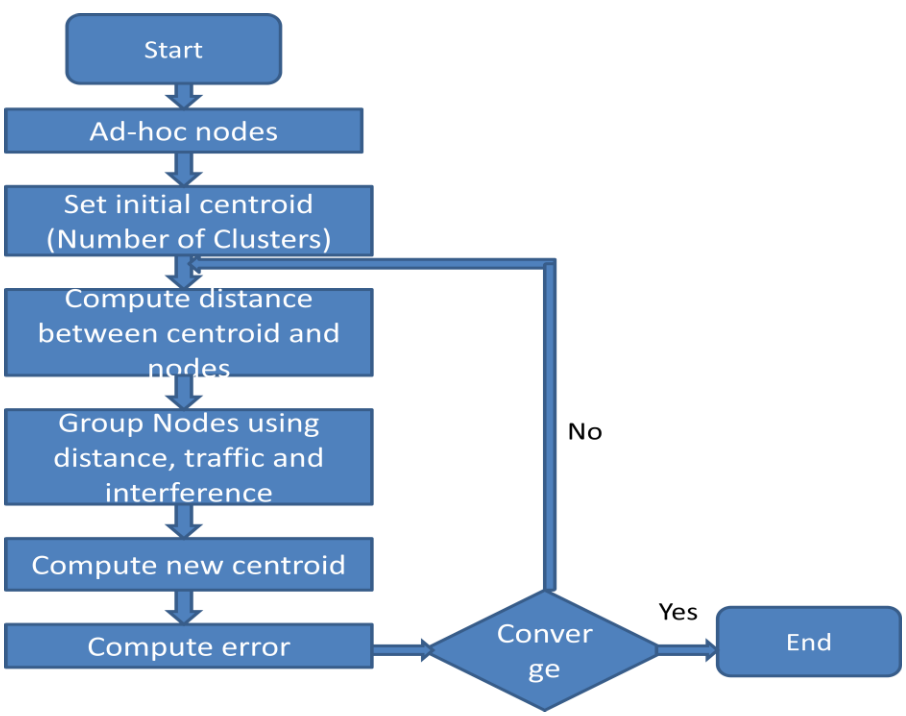


Figure 3: Clustering of Ad hoc Nodes, Stage two

The following equations are used to implement the second stage of the enhanced clustering algorithm. The original distance measure used in the clustering algorithm classifies all ad-hoc nodes $X_i$ as a member of a cluster $C_k$ by computing the minimum Euclidean distance between the nodes and the centroid of the cluster $k$ [1].

The distance equation is given by (1):

$$D(X, C) = (X_i - C_k)^2 \quad (1)$$

Where D(X, C), is the distance between node $X_i$ to centroid $C_k$.

Nodes in the Ad-hoc sub-network that are organized based on the distance between the centroid and the location of nodes does not provide an optimum performance if the nodes are not evenly distributed or if the nodes are evenly distributed and has high traffic in one cluster, then this will make this cluster congested and cause high interference. In order to solve this problem, we add another means of clustering: traffic and interference, for optimal node distribution to each cluster (CC). The expanded algorithm for location and traffic λ is shown in (2): This measure will organize clusters so as to provide uniform traffic across the clusters. This will minimize the mean squared traffic of the clusters and reduce congestion and related delay for QoS performance.

$$D(X, \lambda) = (X_i - C_k)^2 * (\lambda_k)^2 * \frac{var(X)}{var(\lambda)} \quad (2)$$

Where $\lambda_k$, is the total traffic per cluster cell. The terms var(x) and var(λ) represent the variances for the distance and traffic respectively. We multiplied the expanded distance measure equation by the ratio of the distance and traffic variances in order to normalize the units. We discovered that this normalization of the variances of individual variables gave each variable equal weight in the outcome of the clustering.

Finally, the two distance measures, distance and traffic, can be expanded to three distance measure: distance, traffic $\lambda$, and interference I, measure, to minimize the interference caused by the co-channel cluster nodes. This is shown in equation (3). This measure will organize clusters so as to minimize mutual interference from opposite clusters using the same frequency.

$$D(X, \lambda, I) = \left\{(X_i - C_k)^2 * (\lambda_k)^2 * \frac{var(X)}{var(\lambda)}\right\} * I(i, k)^2 * (1 - \rho_{X\lambda I})^2 \quad (3)$$

Where $\rho_{X\lambda I}$ is the correlation coefficient of the two distance measure and interference measure [7] and given by equation (4).

$$\rho_{X\lambda I} = \frac{COV(X\lambda, I)}{\sigma_{X\lambda}\sigma_I} \quad (4)$$

where cov(xλ,I) is the covariance of the two: distance measure and interference measure, $\sigma_{X\lambda}$ and $\sigma_I$ are standard deviation of the distance measure and interference measure respectively.

Distance and traffic are correlated with interference; so we remove the correlation between the three distance measures as in (3).

## 5. SIMULATION RESULTS AND DISCUSSION

This section presents simulation results using a MATLAB program. To see the effect of the enhanced clustering algorithm, a total number of 300 nodes are randomly placed in the x-y coordinate and the GS set at the origin. In order to see the effect of traffic and interference we flood 100 nodes in the first quadrant and 100 nodes in the second quadrant. The first stage is to identify which nodes are in cellular coverage and which are in the Adhoc region. Figure 4 shows randomly placed nodes and partitioned network after applying the threshold SNR value. It is seen that the whole network is separated into CM and AHM nodes. The second stage is the grouping of Ad-hoc nodes based on three distance measures. In this stage the following assumptions are used in our simulation: cluster cells CC#1 and CC#3 use the same frequency (f1) and, CC#2 and CC#4 uses the same frequency (f2). This implies that if more nodes are added in CC #1, the traffic will increase, then CC#3 will have more interfering nodes and the same is true for CC#2 and CC#4. Figures 4 and 5 show the final mixed network after stages one and two of the enhanced clustering algorithm is applied.

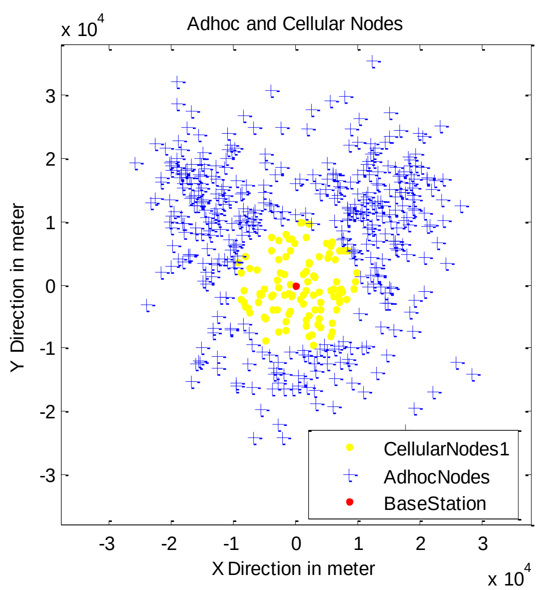


Figure 4: Stage one clustering

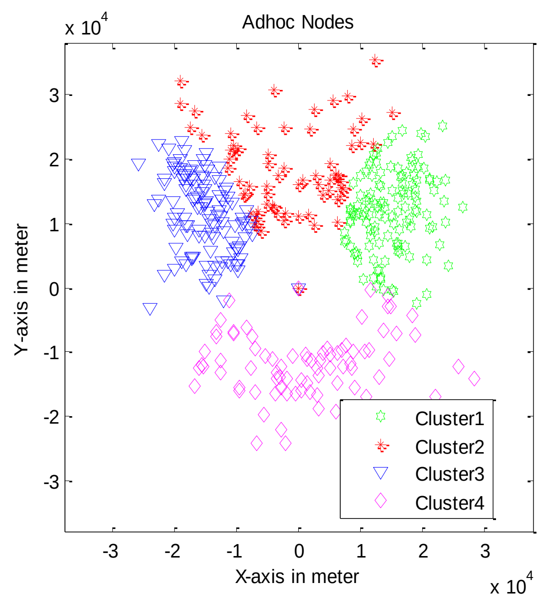


Figure 5: Stage two clustering

The results in Figure 6 show that after the enhanced clustering algorithm is applied, the nodes are more evenly distributed among the four cluster cells based on location, traffic and interference values. This algorithm is the most practical strategy in order to tackle the congestion and interference problems. Figure 6 shows that Nodes from CC#2 distributed to the adjacent cluster cells such that the overall traffic and interference that used to be present in CC#2, is now shared by the neighboring CCs. Figure 7 shows the distribution of traffic before and after the enhanced clustering algorithm.

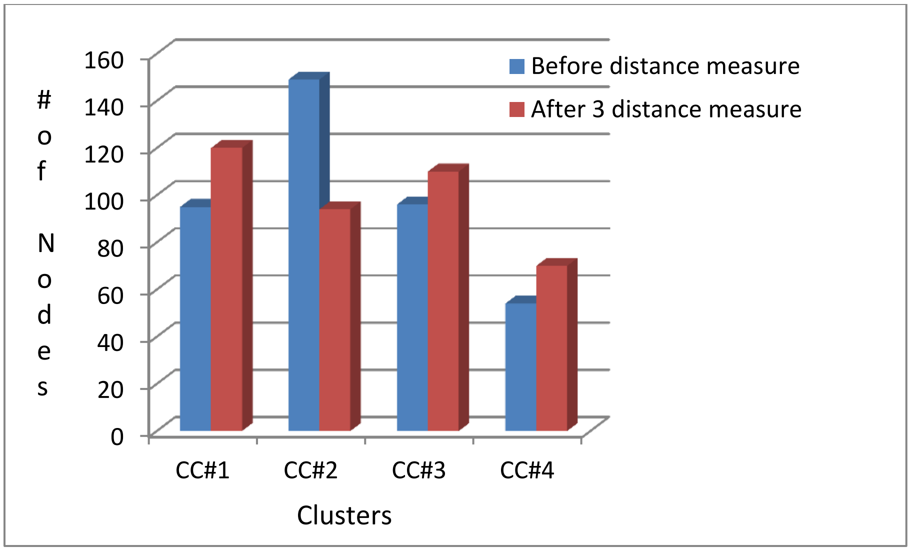


Figure 6: Nodes distribution before and after using three distance measures

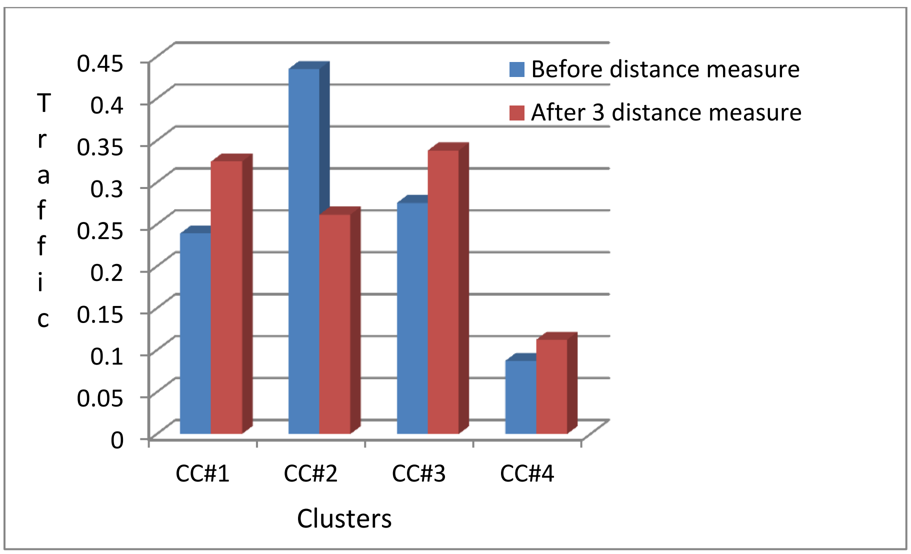


Figure 7: Traffic distribution before and after using three distance measures

## 6. CONCLUSION AND FUTURE WORK

We have shown that the enhanced k-means clustering algorithm which includes signal to Noise Ratio (SNR), Quality of service (QoS), and Interference measure is a powerful tool to cluster nodes for efficient use of the network. We showed using simulation results that clustering can manage the nodes in the ad-hoc sub-network and can jointly optimize the performance of the mixed network. This measure organizes clusters in the way to provide uniform traffic across the network. The simulations showed the optimization of mixed network nodes using distance, traffic and interference measures all at one time. These minimize the means squared traffic of the clusters and reduce congestion and related delay for QoS performance. The next step in our research is to introduce the multiple base stations to the multiple distortion measure schemes.

This will allow us to re-cluster and optimize the performance of the mixed network for QoS applications, traffic and interference management in a multiple Ground stations environment.

## 7. ACKNOWLEDGEMENT

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