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Delivering a Backup File Using Beamformer Antenna for Partially Failed Nodes in a Clustered Distributed Systems for Tolerating Faults

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Abstract. This paper addresses the problem of delivering backup file for two or more partially failed nodes at the same time in a cluster. The design objective is to minimize the maximum transmit power of a backup server and enhance the speed of backup file delivering in allowable time span by utilizing smart antenna and clustering scheme for fault tolerance distributed systems.

In this work we propose Matched Filter (MF), Minimum Variance Distortion less Response (MVDR), Minimum power distortion less response (MPDR), and Minimum Mean Square Error (MMSE) beamformers to track partially failed nodes in a cluster in order to deliver backup file for two or more nodes at the same time.

We have done our simulation using MATLAB to show convergence of beam according to the number of partially failed nodes in a cluster with Signal to Noise Ratio (SNR), to show our propose protocol that is needed for communication among backup servers, backup server with partially failed nodes in a cluster and master backup with agent backup servers and have investigated the performance of our channel model for different scenarios.

Keywords: Distributed Systems, Backup Server, Directional Antennas, Smart Antennas, Clustering, capacity.

1. Introduction

Clustering in Distributed Systems (DS) may address many objectives, such as effectiveness, fast maintenance with tolerating of faults, mobility awareness, and load balancing. The goal of effectiveness can be achieved by grouping all nodes in the networks with a small number of cluster backup servers. This leads to a simple and stable cluster backbone, which facilitates and gives service to the one which needs backup file with tolerable delay [1]-[6].

Therefore, a higher number of simultaneous transmissions could be sustained by the backup server. Beamformer antennas have the ability to concentrate the radiated power towards the intended direction of transmission and possible to deliver different types of backup file at the same time for so many partially failed nodes in a cluster using different Carrier frequency. As a result, they can help reduce the amount of radiated power necessary to reach a node, and thus greatly improve the energy efficiency of Distributed System protocols [7]-[14].

The rest of this paper is organized as follows. In the next section, we discuss our proposed scheme in section 2. In section 3, is presented channel model in the time span of delivering backup file. In section 4, the needed performance results are displayed. Finally, in section 5, we conclude the paper and the last but not the list is the acknowledgement of this work is mentioned.

2. Proposed Scheme

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Assumptions:

- All dead nodes may not be considered at all.
- All member nodes in the network are similar in transmission Power.
- All backup servers in the network have the same transmission level.

2.1. Smart Antenna Model [1][3]

We assumed that a transmitter (backup server in a cluster) is fixed and the receivers are movable. All the signals arriving from the different antenna elements to the receiver are added together and radiated to the position where the receiver found. However, since the elements are separated by distance, the phase of the different signals is different. Let the signal $s_i(t)$ represent the signal arriving at the different antenna elements and let w_i denote the phase and gain that is added to each signal s_i (t). z (t) is the output sent to the receiver and d is distance between elements denoting the phase and gain that is added to each signal. Then, the output sent to the receiver, can be written as:

$$z(t) = A\sum_{i=1}^{M} w_i S_i(t) + N_i = A\sum_{i=1}^{M} w_i s_o(t) e^{ij\beta id\cos\theta} + N_i \tag{1}$$

Where $\beta=2\pi/\lambda$ is the phase propagation factor, λ is the wavelength, and A is an arbitrary gain constant. The weight w_i is used to shift the phase of the signal without varying the amplitude. The representation for the weight is:

$$w_i = e^{ij\beta id\sin s\theta_i} \tag{2}$$

2.2. Protocol Design

- Cluster will be formed according to [1].
- Aback-up cluster head will be selected in each cluster [1].
- Partially failed Nodes that wish to get backup file from Backup Server in a cluster first send an Omni-directional Request-To-Send (RTS) packet.
- A Back-up-Server that receives Request-To-Send (RTS) correctly can do Direction-Of-Arrival (DOA) estimation using one of the beamformer mentioned below and will send a backup files to all nodes that send an RTS to it.
- In the meantime, node A from receiving backup file packet will proceed to transmit acknowledgement data packet on the antenna facing the direction towards Backup Server.
- The master will nominate agent backup servers nearer to it [1].
- Communication will be continued among cluster heads, cluster backup heads with master backup.

The protocols which are utilized to determine DOA in our scheme are:-

1. MF Algorithm (Matched Filter).
2. MVDR Algorithm (Minimum Variance Distortion less Response).
3. MPDR (Minimum Power Distortion less Response).
4. MMSE (Minimum Mean Square Error).

2.3. Physical Model (Antenna Signal to interference Ratio (SINR) [15]

All nodes are assumed to be equipped with a linear array antenna consisting of N elements, and choose a common power P. Let $\{X_k: k\in T\}$ be the subset of nodes simultaneously transmitting at some time instant. A transmission from a node X_i, $i\in T$, is successfully received by node $X_{j(i)}$.

$$SINR_j = \frac{\dfrac{P}{\left|X_i - X_{j(i)}\right|^a}}{N + \sum\limits_{\substack{k\in T\\ k\neq i}} \dfrac{P * \bar{G}_I}{\left|X_i - X_j\right|^a}} \geq \beta \tag{3}$$

$\bar{G}_I$ is the average receiving antenna gain for a random interferer. In the case of the linear array antenna is given by

$$\bar{G}_I = \frac{1}{\pi}\int_0^{\pi} \frac{sin\left(0.25\pi N\left(cos\theta - 1\right)\right)}{Nsin\left(0.25\pi\left(cos\theta - 1\right)\right)} d\theta \quad (4)$$

3. Channel Model

3.1. Input signal to the back-up server

Let the number of partially failed nodes in a cluster be z transmit Request to Send (RTS) of an L-ary pulse $S_y(t)$, the complex total signal at the input of back-up server is:

$$r(t) = \sum_{l=1}^{L} K_l S_y(t - \tau_l) + n(t) = S_y(t) + n(t) \quad (5)$$

Where L is the number of partially failed nodes in a cluster and K_l is the complex fading coefficient of the l^{th} node and $S_y(t)$ is the received y^{th} signal. For a cluster which is sufficiently dense with number of failed nodes, the broad cast of multiple Request-to-Send (RTS) from nodes will be superimposed and the resulting signal S_y will be approximately a nonstationary Gaussian random process:

$$r_z(t) = \sum_{n=1}^{M} K_{m,z} S_y(t - \tau_{m,z}) + n_m(t) \quad (6)$$

3.2. The estimated signal at the output of back-up server [1]

The filtered signal at the output of receiver will be represented by a vector of r(z) = S_y + N(z). The Maximum Likelihood Estimation (MLE) of S_y is:

$$\hat{S}_y = \frac{1}{P}\sum_{i=1}^{P} r(z) \quad (7)$$

Let $E\left\{s_y^2(t)\right\} = \mathrm{P}$, then the Mean Square Estimation Error (MSE) waveforms can be written as:

$$MSE = E\left\{\left\| \hat{s}_y - s_y \right\|^2\right\} = \frac{k_{\max} N_0}{P} = \frac{k_{\max}\mathrm{P}}{PSNR} \quad (8)$$

Where SNR=P/N0. Then the receiver can adaptively update the estimations in a decision directed mode.

We considered a BPSK scheme and designate the centre node as a backup server, the partially failed nodes transmitting an RTS data to flood the entire cluster. Hence, the binary symbols ±1 are sent to a back-up server. Its corresponding complex waveform equivalent is $P_y(t)$, with duration Tp=(1/W) and one-sided bandwidth, W.

$$p_y(t) = s_y\sqrt{W}\sin c(Wt) \quad (9)$$

There are other sources of errors just as channel noise due to nodes in a cluster, neighbour clusters and other white and black noise in the system. If there is no error propagation signal from neighbour, the probability of error is solely determined by the Signal to Noise ratio (SNR):

$$p_{BPSK}(E) = P(m \to \mu) = Q\left(\frac{d}{2\sigma}\right) = Q\left(\sqrt{\frac{2E_o}{N_o}}\right) \quad (10)$$

The signals which are propagated from different nodes will change our original gaussian noise N_o. Now, instead of having N_o gaussian noise variance, it becomes $\sigma = \left\|e_i\right\|^2 + N_o$ and the percentage of backup server that may experience mistakes during detection of signal becomes ϵ. Thus, the error variance is simply E_b times the percentage of nodes that makes a propagation of error signal to the back-up server, $\left\|e_i\right\|^2 = O\left(\left\|z_i\right\|^2 \in\right)$ and the propagated error model becomes:

$$P(E) = 2Q\left(\frac{E_b}{\|e_i\|^2 + \frac{N_o}{2}}\right) \quad (11)$$

$$P_{UB}(E) = 2Q\left(\frac{E_b}{\frac{N_o}{2}}\left(1-\sqrt{(\in)}\right)^2\right) \quad (12)$$

The worst case scenario (near-field), the error propagation leads to an SNR degradation of $\left(1-\sqrt{(\in)}\right)^2$. Thus an upper boundary of the probability of error be designated by equation (12).

Finally, we evaluate performance of the system using different scenarios and the result is depicted in below figure 6 with the following considerations shown in Table 1.

Table 1. Data for simulating BER vs. SNR

Parameter	Type or Value
Modulation	BPSK
c	3 x 10^8(m/s)
BW=Bandwidth	83.5Mbps
N= Number of nodes in a cluster	50
radius	10m
Δt = sampling rate	$\frac{T_p}{10}$
S_y	100mw

4. Simulation Part

4.1. Simulation of Beamformer Antenna using GUI of MATLAB

In this section we present some sample results to show the beam convergence with their SNR by taking the following considerations:

- The power for both Transmitter and Receiver Antenna's is 1.

The results are depicted in figures below.

Initially, a receiver which needs a backup files broadcast an Omni-directional RTS beam as shown below in Figure 1.

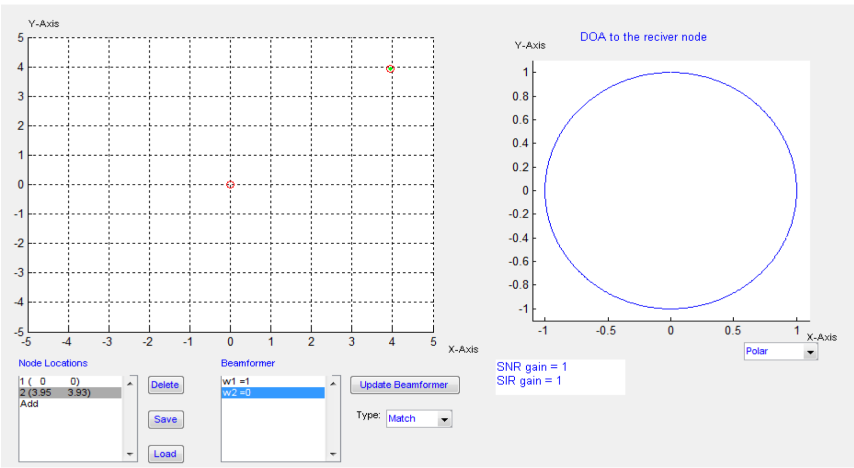
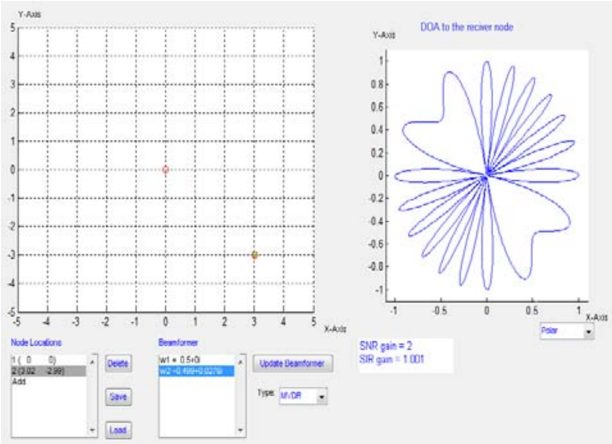
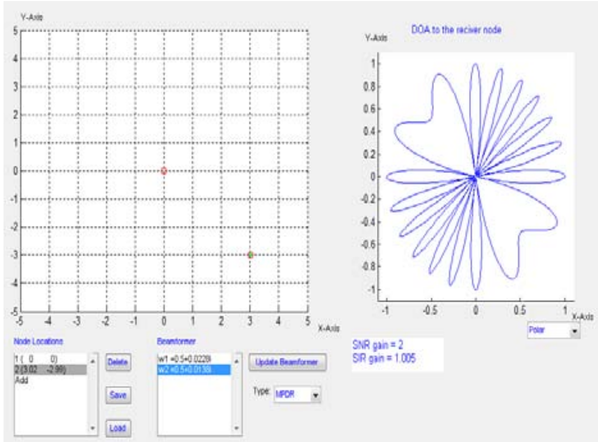


Fig.1: Broadcasting of Request-to-Send (RTS) packet as a beam form from partially failed node in an Omni-directional way

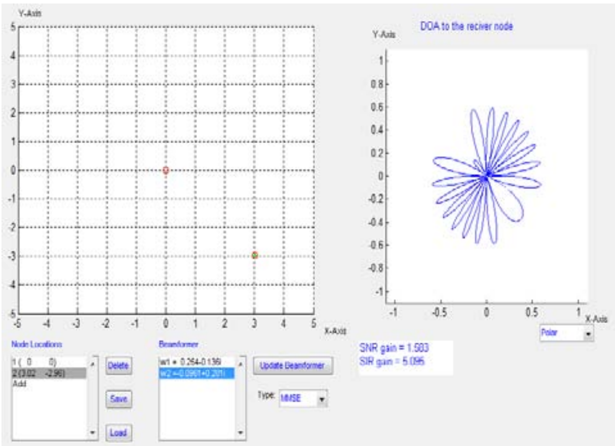
The next step is selecting one beamformer among the above mentioned and pressing the update button. The transmitter then adjusts its maximum power with the beam coverage area towards the partially failed node direction as shown below Figures (For all diagrams, the left part of each figure is used to represent the position of partially failed nodes with movable receivers and besides the middle node is a backup server with a target partially failed node that has green colour).



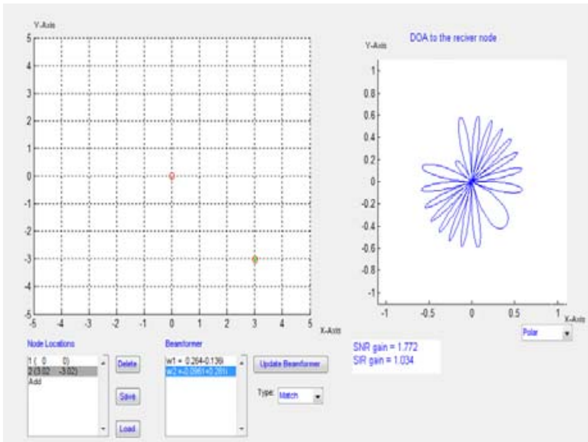
(A) Beamforming pattern for Minimum variance distortion less response (MVDR) Algorithm



(B) Beamforming pattern for Minimum Power distortion less response(MPDR)

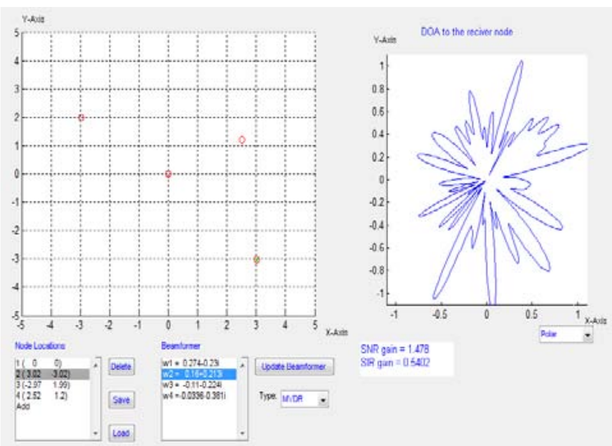


(C) Using Minimum Mean Square Error (MMSE)

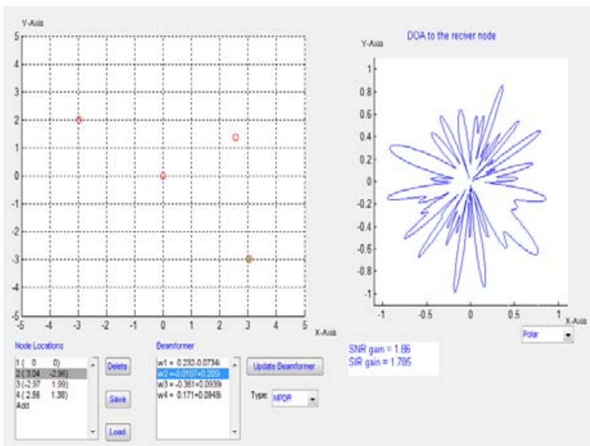


(D) Using Matched Filter (MF).

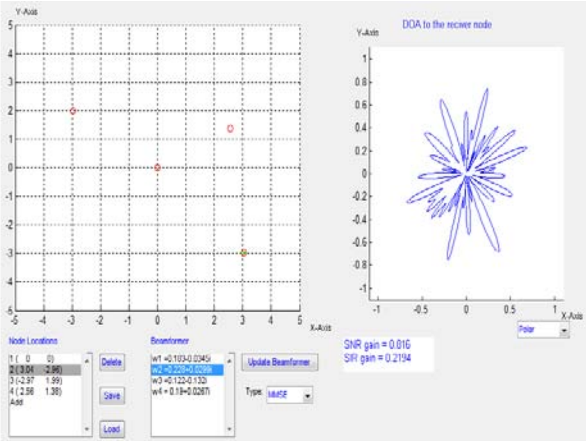
Fig. 2((A), (B), (C), (D)): Beamforming for one partially failed node

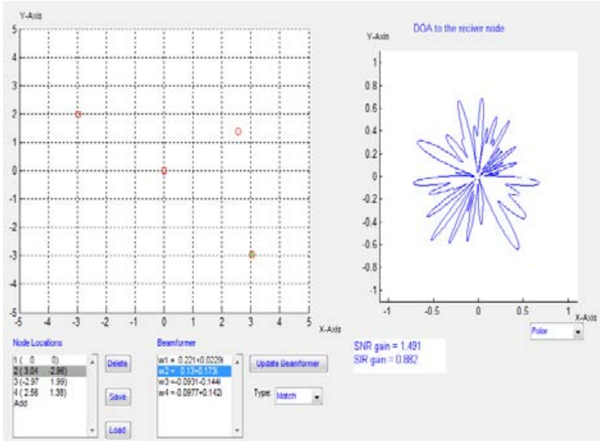


(A) Using MVDR Algorithm



(B) Using (MPDR) Algorithm





(C) Using Minimum Mean Square Error (MMSE). (D) Beamforming pattern using Matched Filter (MF).

Fig..3 ((A),(B),(C),(D)): Beam pattern for three partially failed nodes.

As the number of partially failed nodes increases more and more, the beam pattern is adjusted according to partially failed nodes' position.

4.2. Simulation Part of proposed protocol

In this section we present some sample results to show our proposed protocol that needs to form communication among cluster backup server nodes, cluster back-up server to partially failed nodes and master backup server to agent backup servers.

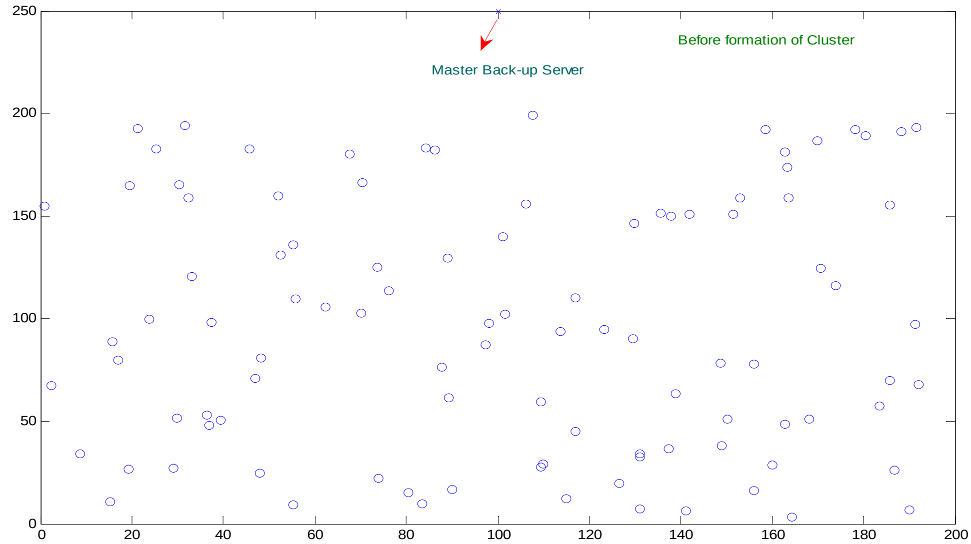
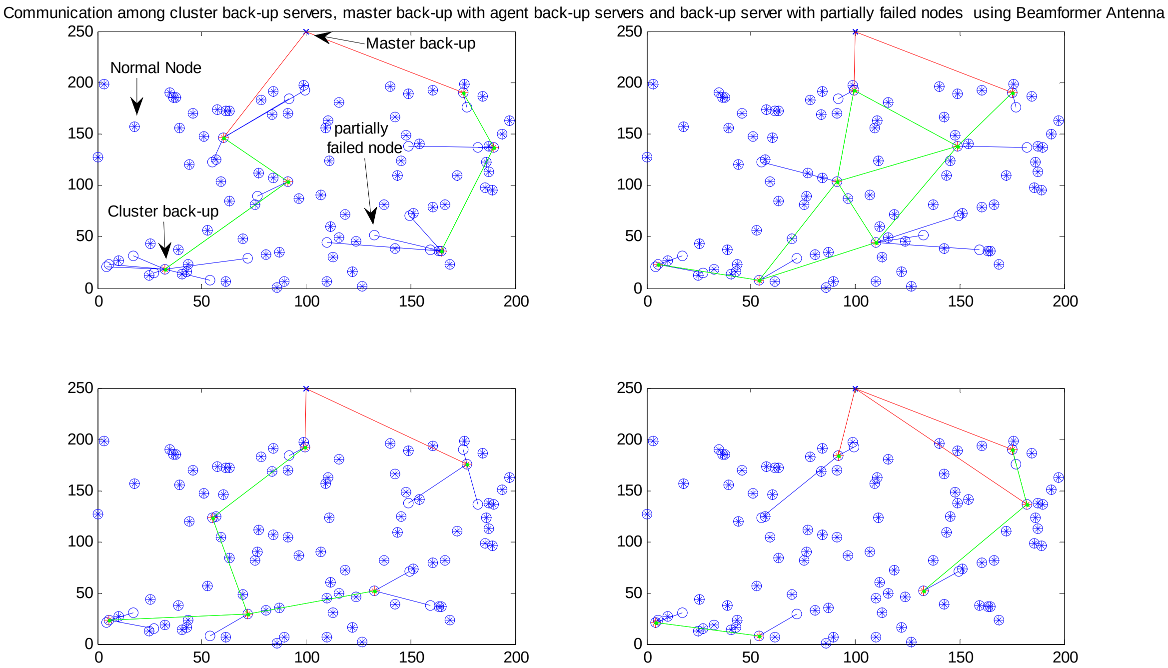
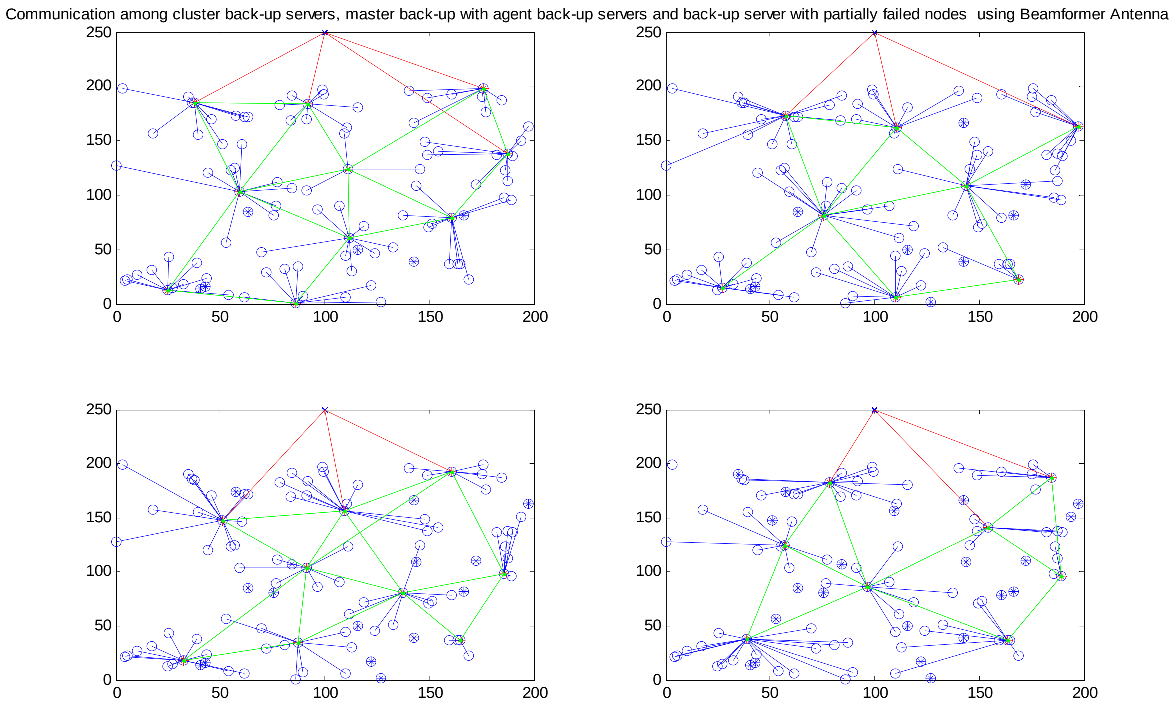


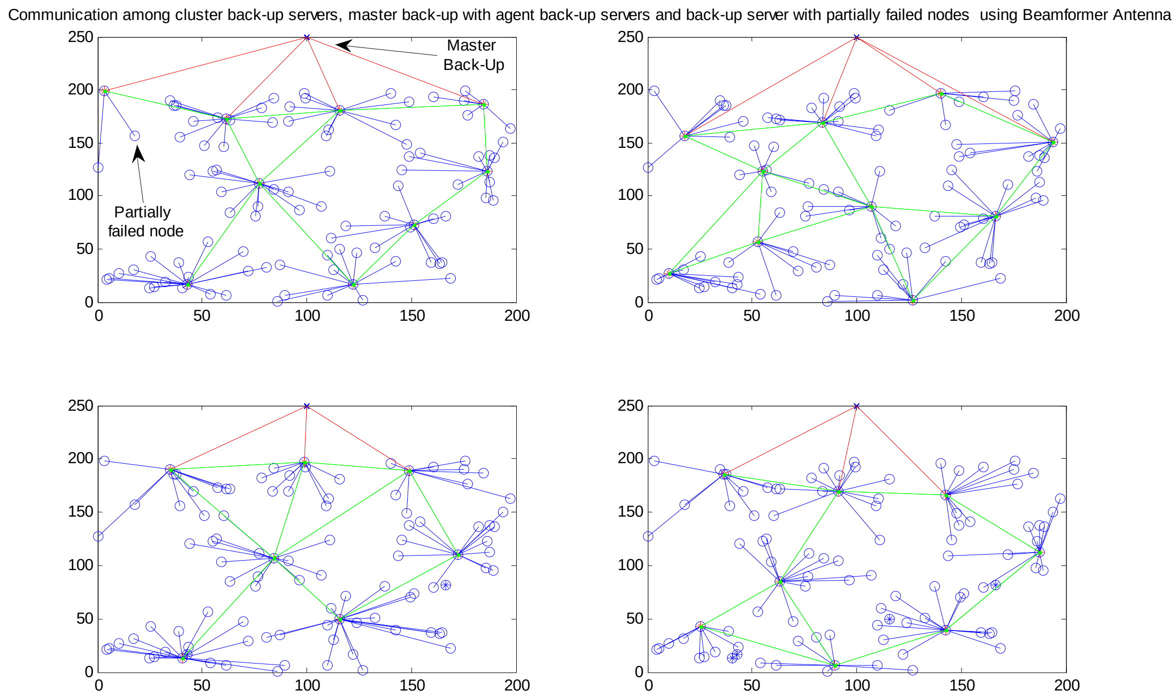
Fig. 4: Nodes before having Cluster


Communication among cluster back-up servers, master back-up with agent back-up servers and back-up server with partially failed nodes using Beamformer Antenna
Master back-up
Normal Node
partially failed node
Cluster back-up

(A)


Communication among cluster back-up servers, master back-up with agent back-up servers and back-up server with partially failed nodes using Beamformer Antenna

(B)



(C)

Fig.5(A,B,C): Cluster formation, election of backup Server and identifing partially failed nodes using the proposed algorithm

4.3. Performance Part:

4.3.1 Channel performance

There are other sources of errors just as nodes in a cluster, neighbour clusters and other white and black noise in the system. Therefore, we evaluate performance of the system using different scenarios and the result is depicted in below figure 6.

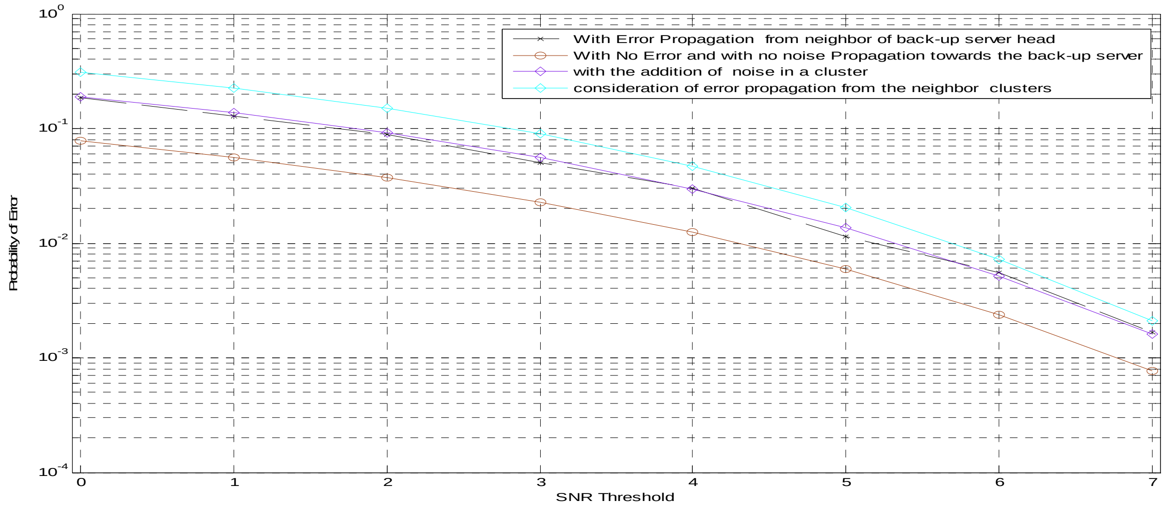


Fig.6: Effect of Error Propagation on performance

4.3.2 Performance of MVDR vs. MPDR

Finally, by varying number of nodes, performances were investigated for MVDR, MPDR, MMSE and MF beamformers. Figure 7 shows the result for the effect of mismatch with distortion constraints for MPDR Vs MVDR protocols.

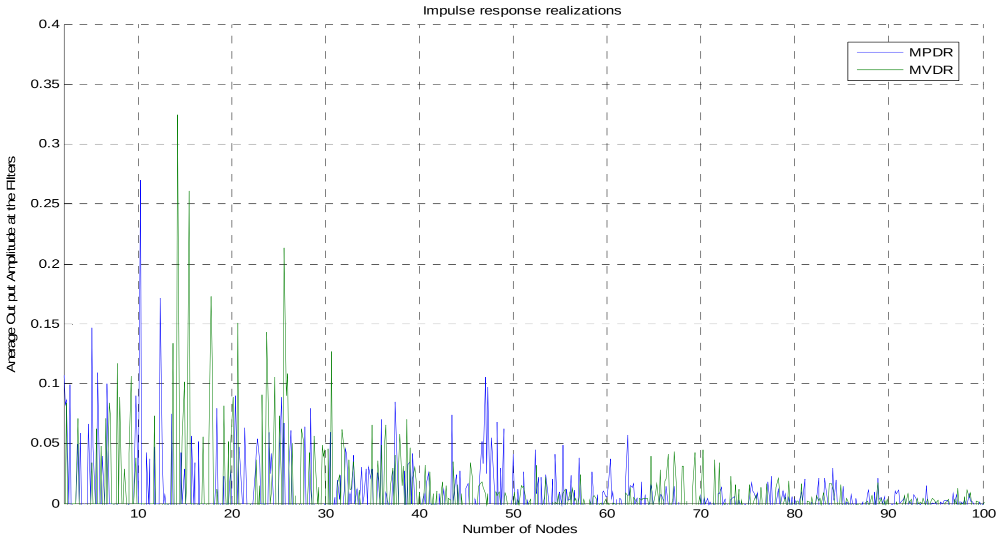


Fig.7 : Impulse respons realization at the out put of MPDR vs. MVDR

5. Conclusion and Discussion

In this paper, we investigated four different beamformers named MVDR, MPDR, MMSE and MF that are invoked for Direction of Arrival (DOA) Protocol which are used to beamformer in a way that maximizes SNR. We notice that among all these, DOA of MVDR beamformer has a faster response than others with higher beam coverage towards the revivers. We studied the impact of using a realistic DOA algorithm as well as the benefits of nulling. Finally, we compared the SNR with Direction of Arrival (DOA) protocols to Omni-directional antenna and observed that it has a gain of 2x – 4x higher than Omni-directional Antenna.

We also developed a protocol which is needed to form communication among backup servers, cluster backup server to partially failed nodes and master backup server to agent backup servers that needs to ensure the life guaranty of network in a fault tolerance distributed systems. This scheme helps to shift the beam of smart antenna towards the needed nodes in the network and can fasten delivering of backup file with a tolerable time span with low transmission power. It can determine the number and size of clusters with a minimum number of backup servers according to the fault existed in a cluster and to the existing traffic situation that selects the appropriate node as a main backup server in each cluster. We also designed the channel model and investigated the problem of interferences from neighbour partially failed nodes, neighbour clusters and even other white and black noises which may exist in the system. Reduce the backbone changes and inter-cluster maintenance overhead and can utilize the cluster stretching mechanism to reduce the leaving rate which affects higher cluster-based protocols.

For the future research, better algorithms may be designed using artificial neural network for backup server election and identifying the position of partially failed nodes and some theoretic analysis should be conducted. One could analyze different channel models in depth, MUSIC algorithm for direction of arrival estimation and different filtering schemes with equalizers and the likes. It is also possible to incorporate more practical constraints or objectives into the model and algorithms.

6. Acknowledgements

We need to say thanks to the editor of this work.

7. References

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