Int'l Journal of Computing, Communications & Instrumentation Engg. (IJCCIE) Vol. 2, Issue 2 (2015) ISSN 2349-1469 EISSN 2349-1477

Beamforming and Interference Mitigation in a wireless network based on Swarm Behaviour

Ranjan Bose

***Abstract*—**We consider a '*swarm*' of mobile nodes that forms a wireless network. The basic idea is that two wireless nodes in the swarm (called the designated nodes) carry out all the computation. These designated nodes then share the results of the computation with all the other members of the swarm, who then use the result along with a location-based correction factor. For example, the designated nodes carry out the computation for the direction of arrival of signal (DoA) from a desired source. This methodology of '*swarm-behaviour*' can be applied for DoA estimation, Beamforming and tracking of the mobile source.

***Keywords*—** mobile nodes, swarm behaviour.

I. Introduction

IT is predicted that many next-generation mobile devices will use Smart Antenna (SA) technology [1]. SA is an antenna-array with smart signal-processing algorithms used to estimate the direction of arrival (DoA) of the desired signal, and use it to calculate beamforming vectors, in order to track and locate the antenna beam of the mobile/target. SA offers a significantly improved solution to reduce interference levels and improve the system capacity. With this technology, each user can transmit or receive only in the desired direction for that particular user. In order to carry out DoA estimation, as well as tracking, a lot of signal processing and computation is required to be done. Computation is expensive both in terms of time and energy.

Swarm behaviour, or swarming, is a collective behaviour exhibited by animals of similar size which aggregate together, perhaps milling about the same spot or perhaps moving en masse or migrating in some direction. As a term, swarming is applied particularly to insects, but can also be applied to any other animal that exhibits swarm behaviour. The term flocking is usually used to refer specifically to swarm behaviour in birds, herding to refer to swarm behaviour in quadrupeds, shoaling or schooling to refer to swarm behaviour in fish. Phytoplankton also gather in huge swarms called blooms, although these organisms are algae and are not self propelled the way animals are. By extension, the term swarm is applied also to inanimate entities which exhibit parallel behaviours, as in a robot swarm, an earthquake swarm, or a swarm of stars.

From a more abstract point of view, swarm behaviour is the collective motion of a large number of self-propelled entities. From the perspective of the mathematical modeller, it is an emergent behaviour arising from simple rules that are followed by individuals and does not involve any central coordination.

Swarm behaviour was first simulated on a computer in 1986 with the simulation program boids. This program simulates simple agents (boids) that are allowed to move according to a set of basic rules. The model was originally designed to mimic the flocking behaviour of birds, but it can be applied also to schooling fish and other swarming entities. Swarm behaviour has been used in various aspects of science and engineering [1-7]. However, swarm behaviour for Direction of Arrival estimation, Beamforming, Source Tracking and Interference Mitigation by nodes in a wireless network has not been explored earlier.

In the proposed paper, we use swarm-behaviour to reduce the overall computation for the 'swarm' of wireless nodes. The underlying idea is that only two of the wireless nodes in the swarm bear the entire computational load and then share the results of the computation with all the other members of the swarm. All the members of the swarm can use this information for Beamforming, after incorporating a location-based correction factor.

II. Beamforming

Consider a wireless network of mobile nodes as shown in Fig. 1. Let us denote the ith node by Ni. Let S be a desired source which can be either stationary or mobile. This source communicates which with every node in the network. Let us assume that each of the mobile nodes is required to estimate the DoA, perform adaptive Beamforming and track the source, S. Such a scenario is common in many mobile applications. Now, the process of estimating the DoA, determining the weight for beamforming and tracking the source is computationally intensive [2–4]. Swarm-behaviour can be used effectively to reduce the over-all computational load of the whole system. We note here that, in many real-world applications, the nodes will be energy limited. Therefore, it is important to use minimal energy for computing the beamforming vector.

Ranjan Bose, Dept of EE, IIT Delhi, Hauz Khas, New Delhi.

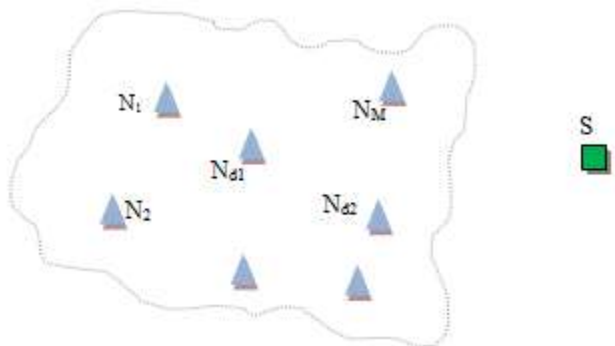

Fig. 1: Swarm of mobile nodes and the designated nodes, N_{d1} and N_{d2}. The source is shown as the green square.

The steps of the 'swarm-behaviour' are as follows:

1. Let there be M nodes in the swarm. Let the ith node in the swarm be aware of it's location (xi, yi).
2. Two nodes, which we will call designated nodes (say, Nd1 and Nd2), perform computation in order to determine the weight vectors wd1 and wd2 respectively. These weight vectors enable the node Nd1 and Nd2 to individually 'look-into' the direction of the source, S. This is shown in Fig. 2. It should be observed that the intersection of the two lines denoting the DoA for the node Nd1 and Nd2 precisely pinpoints the location of the source.
3. The nodes Nd1 and Nd2transmit the weight vector wd1 and wd2 and their coordinates (xd1, yd1) and (xd2, yd2) to all the nodes belonging to the swarm.
4. Each node in the swarm (i = 1, .., M, i ≠ d1, d2) uses its own coordinate information (xi, yi) and that of the designated nodes (xd1, yd1) and (xd2, yd2) to determine a correction factor □wi. This is based on simple geometry, and a look-up table can be used.
5. The ith node Ni determines its weight vector for beamforming simply by calculating

$$wi = wd1 + \square wi. \quad (1)$$

6. Based on the weight vector determined by (1), every wireless node in the swarm can align to the source without having to do the entire computation for DoA estimation. This is shown in Fig. 3.

We note that the same methodology of 'swarm-behaviour' can be applied for tracking of the source. Only the designated nodes carry out the computation for tracking. They will then share the results of the computation with the other members of the swarm, who will use the result with a correction factor, as discussed earlier. Different members of the swarm may be the designated nodes by rotation, or based on resources available. Thus, the more 'energy surplus' nodes can become the designated nodes.

We offer an analogy to swarm-behaviour of a flock of birds. Consider a flock of birds (mobile nodes) looking for food (signal-source). When one of the bird discovers a food-source (i.e., DoA), it (the designated node) broadcasts the location of the food-source to all the birds in the swarm.

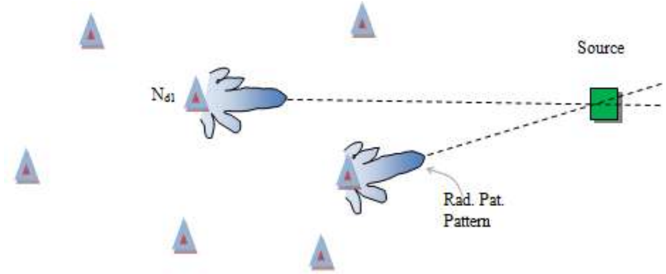

Fig. 2: The designated nodes N_{d1} and N_{d2} compute the DoA and the weight vector required to beamform in the direction of the source.

III. INTERFERENCE MITIGATION

Consider a wireless network of mobile nodes as shown in Fig. 3. Let us denote the ith node by Ni. Let there be an Interferer, I, present, whose interfering signal needs to be mitigated. The interferer can be either stationary or mobile. SA can suitably modify the radiation pattern of the antenna array so as to produce a 'null' in the direction of the interferer. Let us assume that each of the mobile nodes is required to estimate the DoA of the interferer and produce a null in the direction of the interferer, I. Swarm-behaviour can be used effectively to reduce the over-all computational load of the whole system.

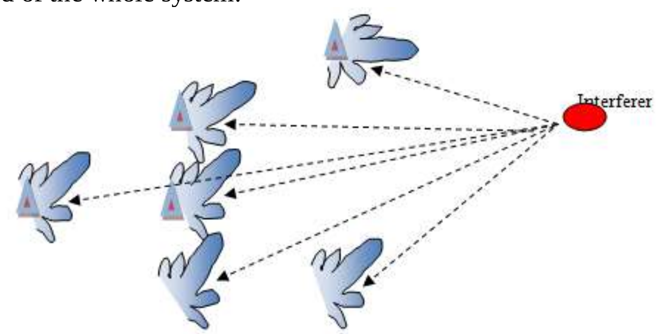

Fig. 3: Based on the weight vector sent by the designated nodes, N_{d1} and N_{d2} , every node in the swarm can create a null in the direction of the interferer without having to do the entire computation for DoA estimation.

The steps of the 'swarm-behaviour' for interference mitigation are as follows:

1. Let there be M nodes in the swarm. Let the i^{th} node in the swarm be aware of it's location (x_i, y_i).
2. Two nodes, which we will call designated nodes (say, N_{d1} and N_{d2}), perform computation in order to determine the weight vectors $\boldsymbol{w}_{d1}$ and $\boldsymbol{w}_{d2}$ respectively. These weight vectors enable the node N_{d1} and N_{d2} to individually determine the direction of the interferer, I. This is shown in Fig. 5. It should be observed that the intersection of the two lines denoting the DoA for the node N_{d1} and N_{d2} precisely pinpoints the location of the interferer.
3. The nodes N_{d1} and N_{d2}transmit the weight vector $\boldsymbol{w}_{d1}$ and $\boldsymbol{w}_{d2}$ and their coordinates (x_{d1}, y_{d1}) and (x_{d2}, y_{d2}) to all the nodes belonging to the swarm.
4. Each node in the swarm (i = 1, .., M, $i \neq d_1$, d_2) uses its own coordinate information (x_i, y_i) and that of the designated nodes (x_{d1}, y_{d1}) and (x_{d2}, y_{d2}) to determine a

correction factor $\Delta \boldsymbol{u}_i$. This is based on simple geometry, and a look-up table can be used.

5. The i^{th} node N_i determines its weight vector for beamforming simply by calculating

$$\boldsymbol{w}_i = \boldsymbol{w}_{d1} + \Delta \boldsymbol{u}_i. \quad (2)$$

6. Based on the weight vector determined by (2), every wireless node in the swarm can align to the source *without* having to do the entire computation for DoA estimation. This is shown in Fig. 3.

IV. CONCLUSION

This paper reports, the use of swarm-behaviour to reduce computational cost for the overall system. It is better than the prevalent techniques because not every node in the swarm is required to carry out the tedious computations, which saves both time and energy per node. This technique is particularly useful for those wireless nodes that are computationally-limited or energy-limited.

REFERENCES

[1] Parrish JK, Edelstein-Keshet L (1999). "Complexity, pattern and evolutionary trade-offs in animal aggregation" (PDF). Science 284 (5411): 99–101. doi:10.1126/science.284.5411.99 http://dx.doi.org/10.1126/science.284.5411.99

[2] Parsopoulos, K. E.; Vrahatis, M. N. (2002). "Recent Approaches to Global Optimization Problems Through Particle Swarm Optimization". Natural Computing 1 (2-3): 235–306. http://dx.doi.org/10.1023/A:1016568309421

[3] Reynolds, C.W. (1987) "Flocks, herds and schools: A distributed behavioral model" Computer Graphics, 21(4), 25–34. http://dx.doi.org/10.1145/37402.37406

[4] Martens, D.; Baesens, B.; Fawcett, T. (2011). "Editorial Survey: Swarm Intelligence for Data Mining". Machine Learning 82 (1): 1–42. http://dx.doi.org/10.1007/s10994-010-5216-5

[5] Bernd Bullnheimer, Richard F Hartl, Christine Strauss, “An improved ant system algorithm for vehicle routing problem ,” in Annals of Operations Research (1999) . http://dx.doi.org/10.1023/A:1018940026670

[6] C. Reynolds, “Flocks, herds, and schools: A distributed behavioural model," Comp. Graph, vol. 21, no. 4, pp. 25-34, 1987. http://dx.doi.org/10.1145/37402.37406

[7] T. Fukuda, T. Ueyama, and T. Sugiura, “Self-organization and swarm intelligence in the society of robot being," in Proceedings of the 2nd International Symposium on Measurement and Control in Robotics, 1992. pp 787–794