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Triangulation Positioning System - Network and Topology Issues

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Abstract—This paper presents ongoing work on localization and positioning through triangulation procedure. Issues of scalability and topology are also examined and areas that are problematic and need further analysis and implementation in the network are analyzed. In a Fixed Stations Network, as it was presented in [1] a triangulation problem is becoming high complicated when we have a large number of sensors and transmitters.Sensors bearings and data readings have to be checked on a case by case basis.The combination and processing of a vast number of data needs filtering and implementation of the various cases, whilst synchronously data processing in various stages can provide accurate results.

Keywords— Fixed Stations Network, Triangulation, Localization, Network Topology, Scalability, Triangulation area.

1 . INTRODUCTION

The problem of localization is under research recent years and as the applications of Sensors Networks are spread year by year in many fields, ways to find the position of a Sensor or a Transmitter with high accuracy are still tested and remain of high importance. One of the localization techniques is the process of Triangulation which was analyzed in [1]. It was also shown that in a large network with a great number of Sensors - SRs there are cases of pseudo transmitters PTRNs which need to be examined on a case by case basis. The concept of this paper is to shed light on various issues that should be put into consideration when a Sensors Network - SN has to work as an automated system. Various cases will be analyzed and it will be shown that for an automated network with many SRs and a great number of TRs that operate in an area of interest, there are attributes that need great attention and need to be examined and integrated in the system.A fixed stations network isn't able to move it's SRs but with logical programming it can analyze and combine the SRs data and provide valuable results. Results with high accuracy will be acquired and transmitters positions will be revealed.

2. TRIANGULATION AREA

Triangulation area -TRN is the result of more than two bearings intersection. The intersection common area of the sensors - SRs beams is the area of triangulation. As it is depicted in Fig.1 and Fig.2 triangulation - TRN area size is analogous to distance of the SRs and the intersection point. It can be seen that the TRN area in Fig.2 is much smaller compared with Fig.1 ,where the distance from the SRs is less compared with the distance between the TRN area and the SRs in Fig.1. For that reason the distance parameter should be taken into consideration with relative cautiousness as a large area of triangulation can cause undesirable effects in the network.

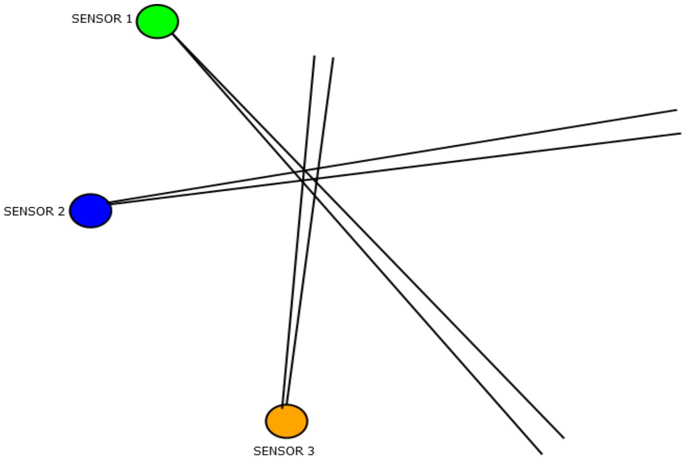

Figure 1

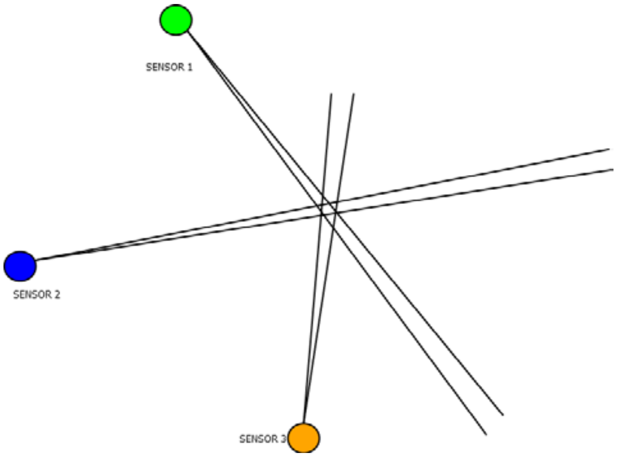

Figure 2

3. TRIANGULATION IRREGULAR CASES

In the detection area it isn’t for granted that finding a transmitter-TR position is an easy procedure.There are a lot of irregular cases that might decrease the network’s performance and provide false results. In Fig. 3 we can see that even if one SR is close to the triangulation area, if another transmitter -TR is projected at an extension line that intersects the TRN area then its bearing is irrelevant with that area. If more than one TRNs are in such a condition then the issue of TRN becomes more and more complicated and the network should be able to reject false triangulations.

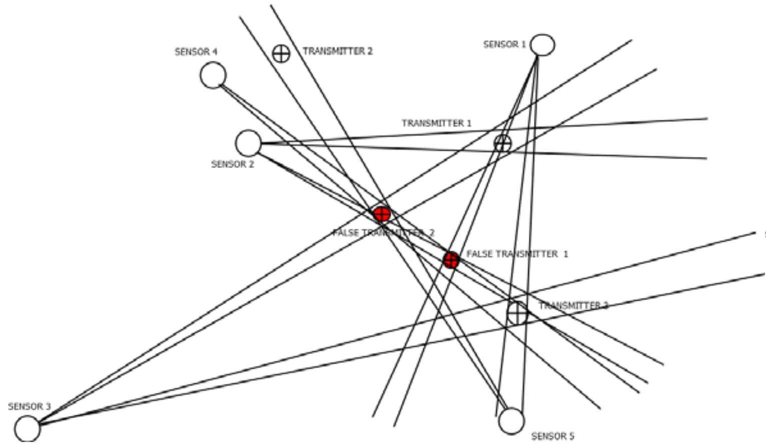

Figure 3

Also,as it is clear in Fig. 4 the three SRs doesn’t triangulate. Their bearing intersect in pairs and doesn’t have a common area all of them.Another irregular is a case in which if a TR is at a great distance from the TRN area then its beam covers a large area Fig.5, and doesn’t give clear results. It is a condition in which a SRs beam covers the three intersection areas C1,C2,C3 which are close and the system might assume that there are three different TRN areas. It is a complicated case which need to be implemented with adequate programming.

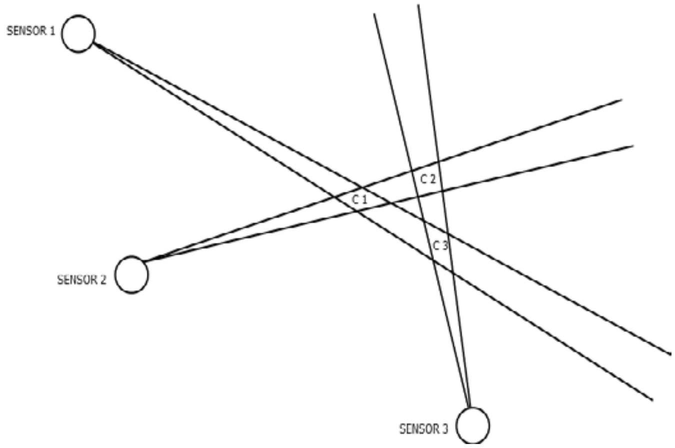

Figure 4

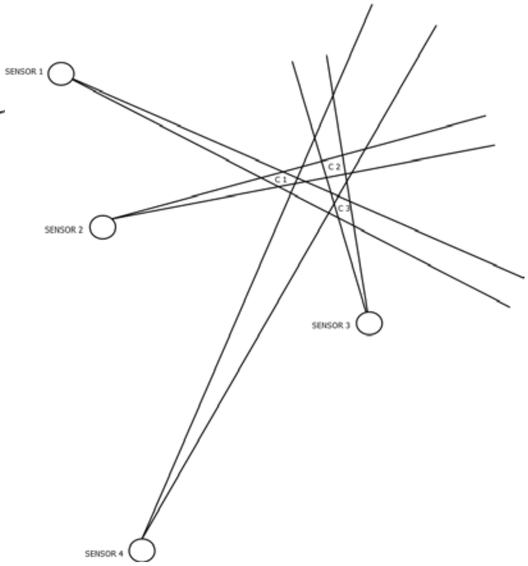

Figure 5

In such a case a filter related with distance should be implemented.To that we can add that the distance from the TRN is a parameter that might also be incorporated in the case of searching TRs with high power. It is a condition in which a TR will be detected from a SR at a great distance due to it’s high power Fig. 6.

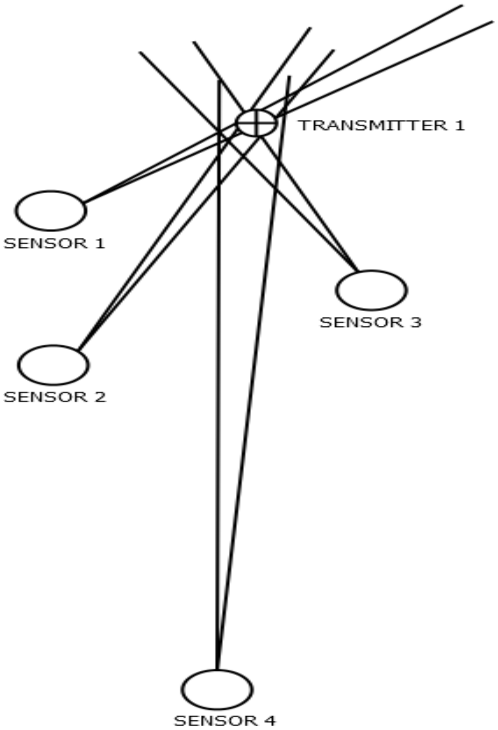

Figure 6

When the distance between a SR and a TR is large, the TR is detected due to it's high power.A TR which isn't detected due to it's low power, might be detected by other SRs which are close.

3.1 LONG DISTANCE SRS-FALSE TRIANGULATION IRREGULAR CASE

As it was mentioned before and showed in Fig.5 a SR whose position is far from a non triangulation area may overlap the triangular regions of intersection and provide false results to the system.In Fig.7 we see three SRs and lines(bearings) in the north area of Crete island.The lines depicted are lines with error (plus-minus error and the bearing.Minus bearing is depicted with red colour, bearing with orange and plus error is black colored)

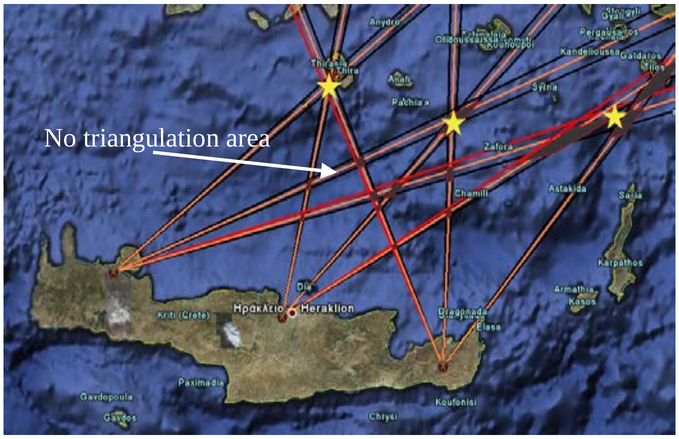

Figure 7

The triangular area of non-triangulation is depicted more clearly in the following **Fig. 8.** The areas of bearing intersections are grey colored.

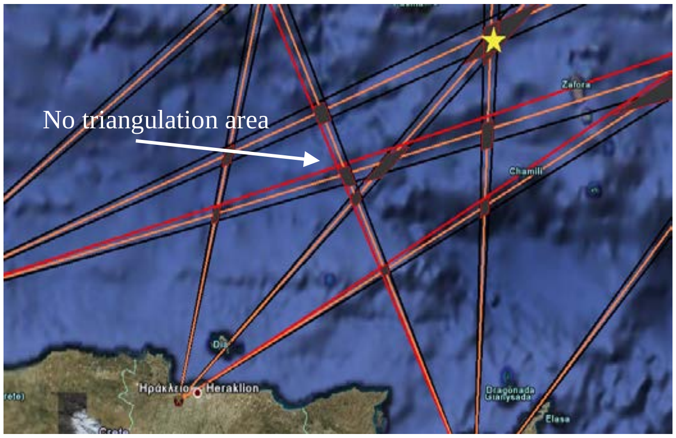

Figure 8

In Fig. 9 we see another SR that has a bearing that passes over the Non-triangulation area and its position is far from that area.The outcoume of that intersection is that in the system there is added a number of false TRNs as pairs(in this case we have three more false TRNs, although there is no TRN case in that area. This problem has to be tackled adequately as if this condition appear in many similar areas and with many SRs whose bearings are passing over them will overload the system with false TRNs.In Fig.10 that area is depicted more clearly and that area is problematic for every bearing that passes over it.

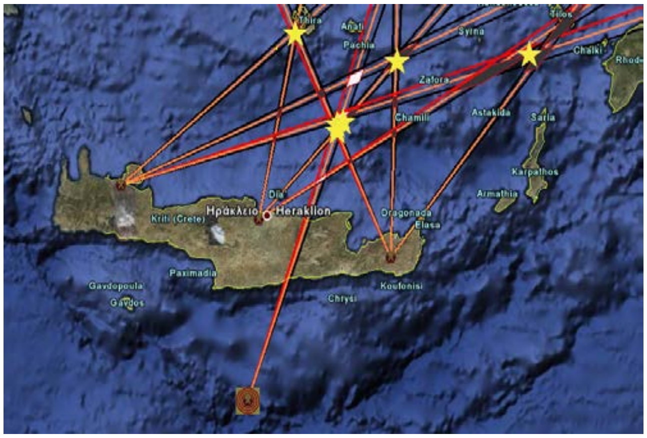

Figure 9

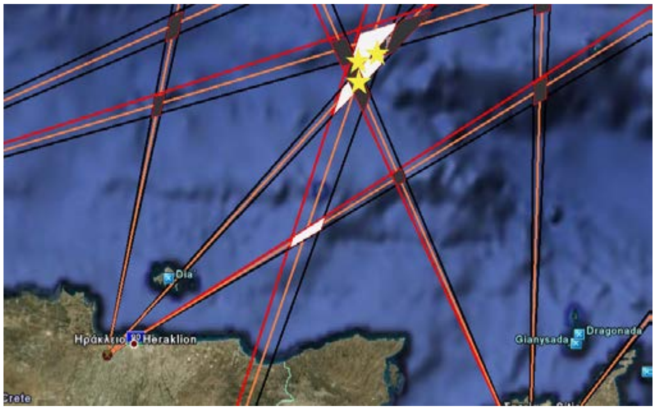

Figure 10

3.2 INCREASED BEAM ERROR - FALSE TRIANGULATION IRREGULAR CASE

Another similar case is the case which is depicted in the following Fig.11. Here it is depicted the TRN which results from the error parameter change, (the beam error is increased). As the error is increased, the width of the beam is increased and the three areas intersect.Again the TRN which is depicted is a false triangulation - FTRN. By that way and by increasing the error of the beam we can also distinguish FTRNs in which beams are close to each other but don’t intersect.The system them will be able to count the number of FTRNs in relevance with the SRs beam width. In Fig. 11 we can also see that the size of the error polygons C1,C2,C3 is also increased.

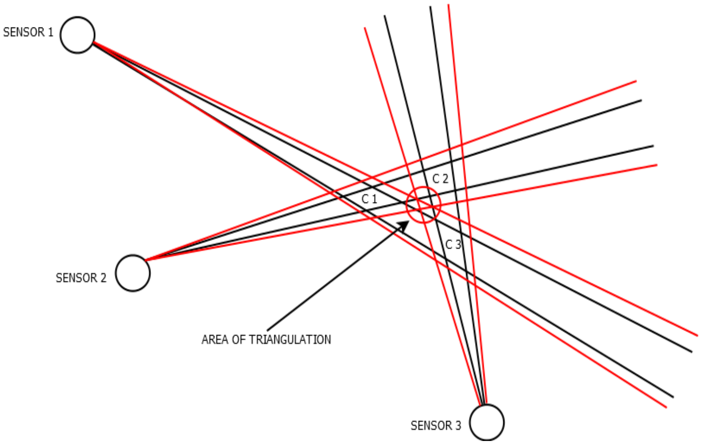

Figure 11

3.3 BEARINGS EXTENSION TRIANGULATION IRREGULAR CASE

In the TRN area which is depicted in Fig. 12, SR1, SR 2, SR3 bearings intersect and triangulate and detect TR1. There is another TR2 which lies close to that area and on the extension line of bearing two- BRNG2. In this case the TR2 might be rejected by the system and the triangulation area TRN2 might be rejected by the system as the intersection is related with the extension line of BRNG2.This problem can be tackled by activating a SR or SRs close to that area. If SR6 intersect with the SR4 and SR5 then we have a true TRN.

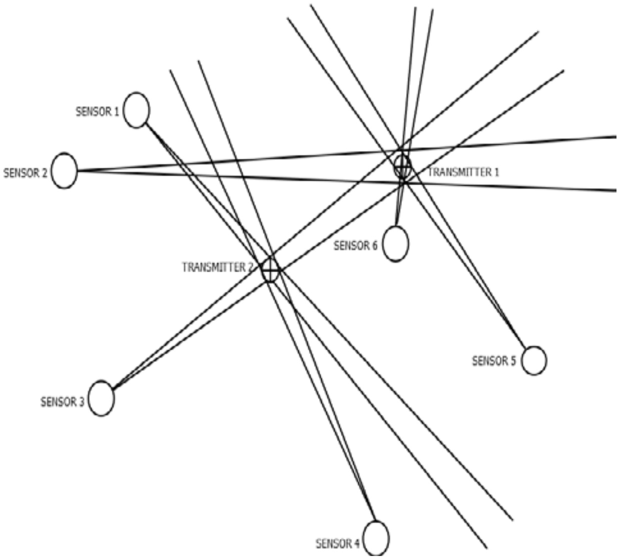

Figure 12

3.4 SENSOR TO SENSOR BEARING FALSE TRIANGULATION CASE

As it is depicted in the following Fig.13 in this case we have many intersections of beams between the SR 2 and the SR 3 due to the fact that SR 2 bearing is pointing towards the SR 3.The SR 3 bearings 1,2,3, and 4 will intersect with the SR 2 bearing and provide intersections.In Fig. 14 we see how another SRs bearing SR 4 which also is pointing towards SR 3 will result in many FTRNs. And as other SRs bearings will passing from that area then the situation will become more complicated and will overload the system with thousands of calculations and data that aren't needed. Bearing in mind that for hundreds or thousands of SRs providing their data in an area a great number of irregular intersections will result in triangulations and we can easily assume that the number of FTRNs will increase rapidly.

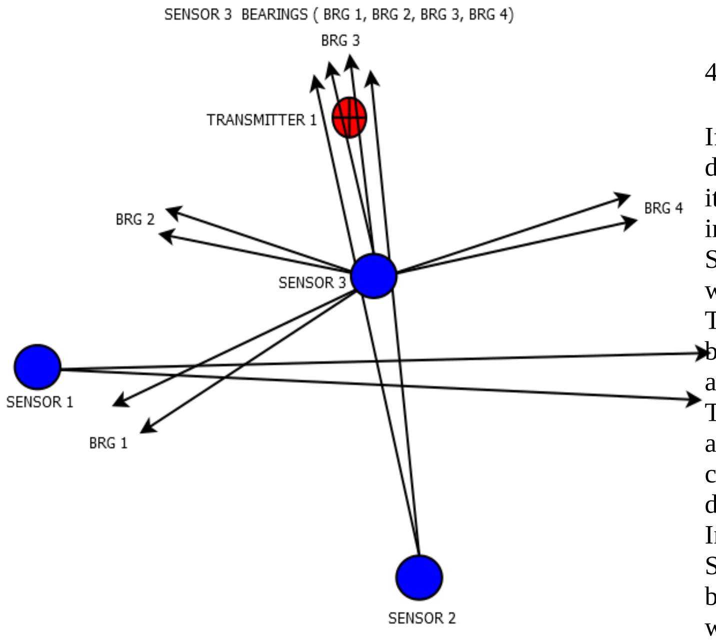

Figure 13

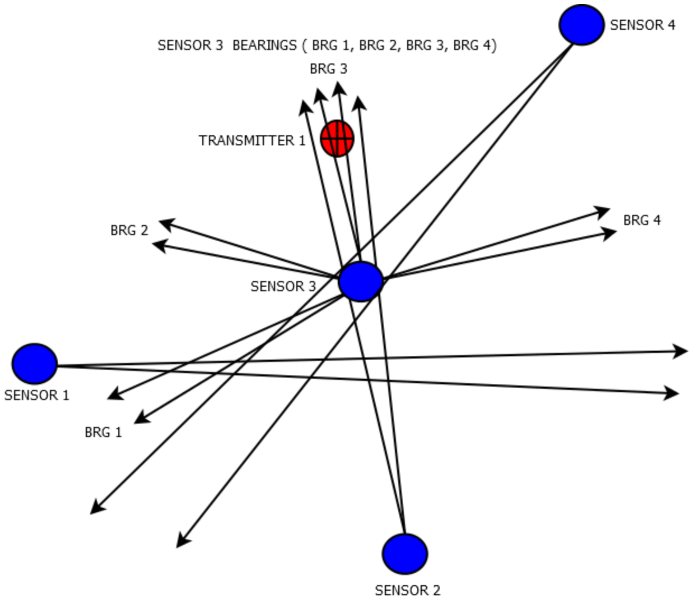

Figure 14

4. MORE THAN ONE TRs IN THE TRN AREA

If more than one TRs lies within the TRN area then the detection issue becomes more complicated for the network. As it can be seen in Fig.13 TR1 is detected whilst TR2 is covered inside the TRN area.The way to tackle this problem is another SR which is close to the TRN area. That SR due to it's low width of beam (as it is close to the TRN area) might detect TR2. The distance of SRs that will be able to detect TR2 can be calculated, as it is analogous to the distance of the TRN area.Knowing that a SR close to the TRN area detects another TR then we might easily find the other SRs which will also be able to detect TR2.That means that with adequate level of coverage in one area we can use SRs data depending on the distance from the area of interest.

In Fig.15 we see a circle and a SR which lies out of that circle. SRs that lie within the circle are close to the TRN area and will be able to detect the second TR. SRs that lies out of that circle will detect at least one TR like SR4. In Fig.15 we also see the problematic areas within the circle which will provide irregular areas of TRN. Those areas are those which exists inside other SR's beams.And SRs that are outside that areas will not be able to detect the extra TRs in that area.

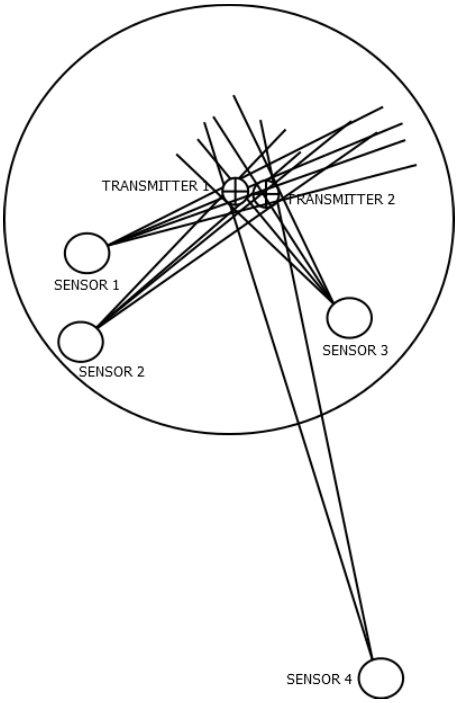

Figure 15

In [2], an algorithm for detection and tracking of multiple targets by using bearings measurements from several sensors was developed. The algorithm is an implementation of a multiple hypothesis tracker with pruning of unlikely hypotheses. Tracking conditional on each hypothesis could be performed by using any suitable filtering approximation. Also, a range parameterized unscented Kalman filter was used. Each hypothesis described a track collection with varying number of targets. Final track estimates were obtained by weighted clustering according to hypothesis probabilities and clustered track states. Simulation experiments included arbitrary setup of multiple targets and multiple moving receiver platforms (sensors).

In [3] Bishop et al. examined the problem of optimal bearing-only localization of a single target by using synchronous measurements from multiple sensors. They approached the problem by forming geometric relationships between the measured parameters and their corresponding errors in the relevant emitter localization scenarios. They derived a geometric constraint equation on the measurement errors in such a scenario. They formulated the localization task as a constrained optimization problem that can be performed on the measurements in order to provide the optimal values such that the solution is consistent with the underlying geometry. They also illustrated and confirmed the advantages of their approach through simulation, offering detailed comparison with Traditional Maximum Likelihood estimation TML.

4.1 GHOST TARGETS

Ghosts targets are a phenomenon that occurs for bearing only sensors and many methods can be used for elimination or reduction of them [5].In [4], there are discussed some theoretical conditions for unique localization of multiple targets using the intersection of multiple bearing lines in the presence of the data-association problem. Mazurek et al in [5] are discussing all the necessary theoretical requirements to solve the so-called ghost node problem, which appears in Fig.16 , and it is illustrated that it is by no means possible to assume that three spatially distinct bearing sensors are sufficient to eliminate the so-called ghost node problem. In Fig.17 and in Fig.18 it is clearly depicted the definition of ghost emitters with two and three SRs respectively.

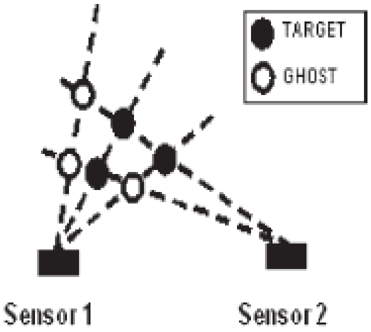

Figure 16

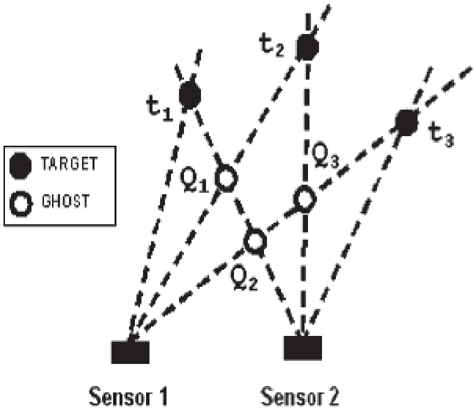

Figure 17

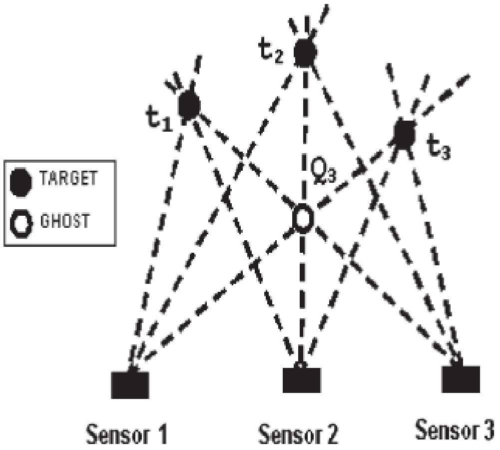

Figure 18

Also, theoretical conditions which are required to solve the ghost node incarnation of the so-called data association were explored and a maximum bound on the required number of ideal measurements was derived, along with a probabilistic model that shows the decay of the number of ghosts as a function of the measurement (sensor) numbers via simulation and ghost suppression techniques were presented related with the target area, Fig.19 and Fig 20.

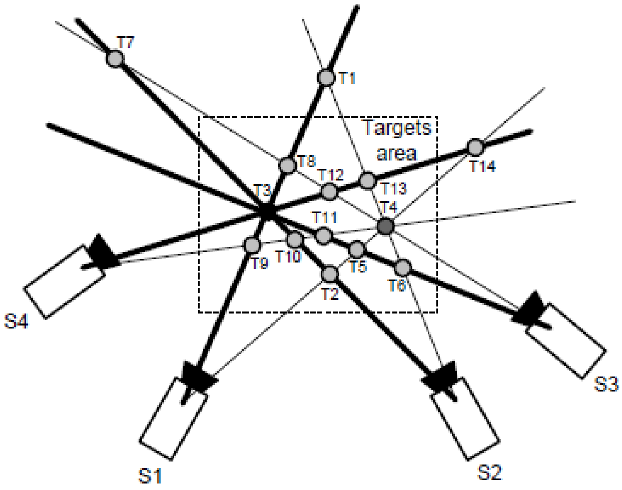

Figure 19

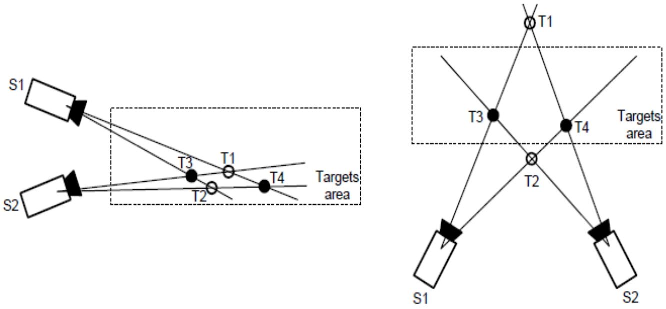

Figure 20

In addition to that, it was commented that ghosting is a very serious problem for serious application and that for a specific case one method can be better in comparison to others but can fail in another case and all of them should be used carefully. Deghosting methods were used with Track-Before-Detect - TBD algorithms directly, without additional post processing. In [4], a novel multitarget bearings-only tracking algorithm that combined the fuzzy clustering data association technique together with a Gaussian Particle Filter (GPF) was presented. To deal with the data association problem that arises due to the uncertainty of the measurements, the fuzzy clustering method with the maximum entropy principle was utilized, and a GPF was employed to update each target state independently. Moreover, in the multisensor scenario, a statistic test method based on the cotangent values of bearings was proposed, for associating the target bearing data observed at each sensor.Simulation results demonstrated the effectiveness of the algorithm.

4.2 GHOST TARGETS -MISSING TRANSMITTER

In an area that we have a lot of SRs and TRs there are special cases where real TRs might be rejected from the system as they might be taken as a result of FTRNs or ghosts.One such case is depicted in the following Fig.21. SR 1, SR 2,SR3 and SR4 are detecting TRs in the area and their bearings intersect in the center of the circular area. That happens when some TRs are placed in a circular manner around another TR. Here the system rejects the TR in the center of the area as it is assumed to be a ghost target. If then the system doesn't use adequate data association that target will be missed. The system assumes that the target is a ghost as the lines intersect in the center of that area but are related with other targets which lie on the extension of those lines.

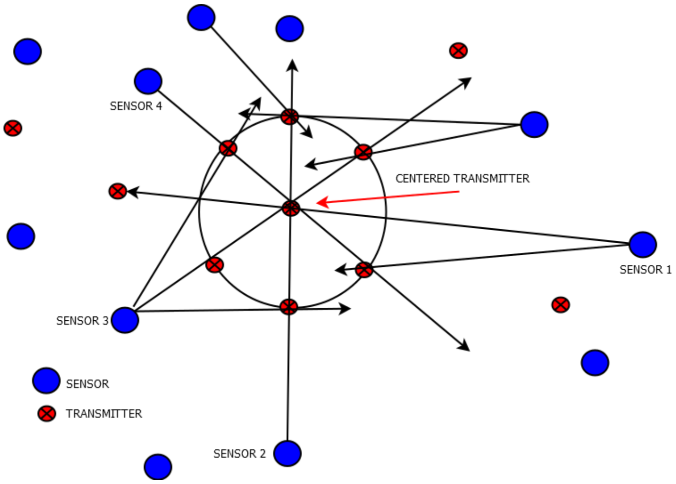

Figure 21

5. DETECTION AREA

Inside the detection area there might also exist cases of uncovered areas, irregular areas and hole problems.Network topology should be carefully designed in order to deal with those problems in combination with relative software ways to process the data and provide true TRNs. Network architecture and scalability also should be taken into consideration as undesirable TRNs which will provide false results might supplant the network's overall performance.

5.1 DETECTION AREA PARTITION

A way to enable the network to work more properly and offer better TRNs is area partition. As the whole detection area will have problematic areas, hole problems and irregular TRNs, the detection area should be divided in sub-areas for TRNs processing.In [6] it is showed a model which divides the wireless sensor network sensors into groups. These groups communicate and work together in a cooperative way. Thus they save time of routing and energy of WSN. In addition it is showed how organizing the sensors in groups can provide a combinatorial analysis of issues related to the performance of the network.In [7] it is investigated a strategy for energy efficient monitoring in WSNs that partitions the sensors into covers.Then, the covers are activated iteratively in a round-robin fashion.

That approach takes advantage of the overlap created when many sensors monitor a single area. Two deterministic algorithms are presented and simulations indicated that the increase in longevity is proportional to the amount of overlap amongst the sensors. Algorithms are fast, easy for usage, and according to simulations executed, they significantly increase the longevity of sensor networks. Also, in [5] the fundamental issue of *coverage* in sensor networks is examined, which reflects how well a sensor network is monitored or tracked by sensors. A solution is proposed to find out the degree of coverage in a sensor network with irrespective of same and different sensing range. We consider the intersection area & try to find out in a mathematical way using set theory method. They proposed a simple and efficient model for easily finding the degree of coverage. In our case which is different and is depicted in Fig.22 we see that the detection area is divided in four large square sub-areas which are numbered form one to four and each of them is also divided in two other smaller areas which are numbered 1.1, 1.2 … 4.1 and 4.2. By that way we have a total of eight triangular shaped small areas. This area partition can be used to process the data for TRNs, avoid false TRNs and synchronously detect hidden TRs which are the cases previously mentioned. Each area includes a number of SRs. When the system collects all the data, the set of BRNGs of the SRs, then the software should not use all of them in order to provide TRNs. Processing will have to be performed in different stages and area by area, and that will add more accurate results.

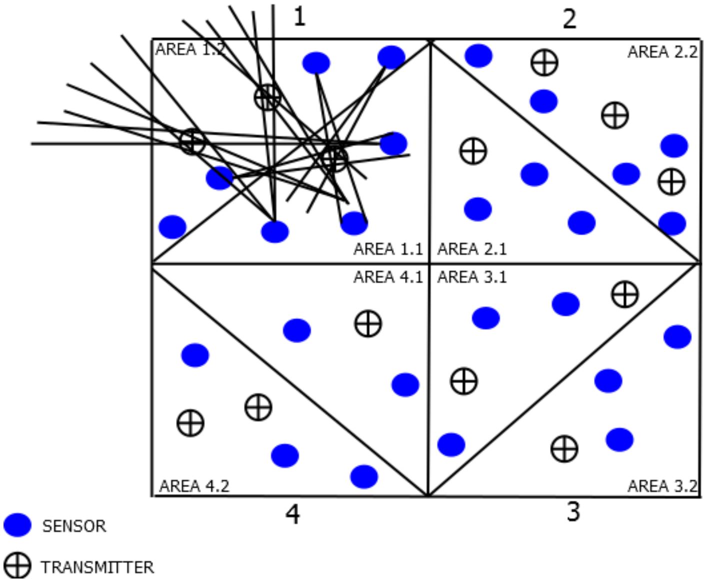

Figure 22

5.2 NETWORK TRIANGULATION ALGORITHM

An algorithm which will enable the previously mentioned network with eight triangular shaped areas for TRNs is needed to be implemented. That algorithm will use data for processing in different steps and will provide more true TRNs whilst synchronously will diminish false TRNs.One such algorithm is the following:

-Area for detection:	Area 1
-SRs BRNGs for calculation;	SRs of squares 2,3,4
-TRNs results	5
-TRNs in area 1.1	2
-TRNs in area 1.2	3
-SRs in area 1.1	3
-SRs in area 1.2	5

-SRs in area 1.1 search for TRNs in area 1.2

-SRs in area 1.2 search for TRNs in area 1.1

As it can be seen ,the algorithm processes the data in various stages. While searching for detection TRs in area 1, at first stage only the data of the other three areas, two , three and four are calculated. At the next stage the data of the triangular shaped sub-areas 1.1 and 1.2 are implemented. In this stage TRNs of SRs that lie within area 1.1 are used for detection of TRs inside area 1.2.Respectively, SRs of area 1.2 data are processed for detection of TRs inside area 1.1. By that way TRs that haven't been detected by SRs of the other areas (2,3,4) will be detected due to the low width of area 1 SRs beam that are close to them.Synchronously, in the second stage of processing real TRNs will be confirmed whilst false TRNs will be rejected. The method can also find various applications [9] and [10].

6. CONCLUSION

As a conclusion we can mention that for a fixed stations network -FSN which has to perform in an autonomous way, a lot of parameters should be examined carefully. Furthermore, the arrangement of nodes is also related with the efficiency of a FSN, and a proper arrangement can increase its performance.We saw that being accurate a fixed station network system it should be able to calculate the data of many SRs whilst synchronously process them in various stages and steps, as many irregular cases of TRNs will affect it's performance. Data association in combination with processing in different stages might allow for accurate results. Future work might involve other network attributes like topology, SRs power and further analysis of the distance parameter.

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