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ATCD: Angle,Time,Coordinates and Distance Based Multilateration Localization for MANET

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Abstract: *Mobile ad-hoc network is a wireless communication supported infrastructure network having high mobility and dynamic topologies. The nodes are continuously in motion causes dynamic change in their position updates which generates a burdensome for them to handle this without any hardware infrastructure elements. Localization is divided into two major categories of range based and range free. Range free localization requires high node density and its accuracy depends on the network topology. But sometimes there node density is not available and then the system generates the weak location estimates. Also the environmental factors such as time synchronization and accuracy are not handled properly in range free localizations. The objective with this work is to improve the localization accuracy with fewer resource constraints and reduce the dependencies on any additional hardware devices. During the study we also found that there is no uniform test bed available for implementing or simulating the concept properly. This work suggests a novel ATCD approach which uses multilateration based localization for MANET.*

Keywords: MANET, Localization, Range based, Angle of Arrival (AoA), Time of Arrival (ToA), Multilateration, ATCD, Accuracy.

1. Introduction

Wireless communication is changing very rapidly due to heterogeneous device supports and high user counts. The wireless medium supports mobility based communication which somewhere provides portability and device independence. It is based on radio communication at different ranges and on the basis of which they can be separated or designed. A wireless ad-hoc network is a temporary established links with decentralized controls. It does not depend on the preexisting infrastructure and each time when
communication is desired new connection is established. Here each node is responsible for supporting the routing process and holds the dynamic connectivity. While considering the mobile operations and environment, ad-hoc network are basically represents peer to peer network. Here the data and control packets are transmitted using store and forward manner from selective source to desired destination. Wireless networks can be classified based on the connectivity types of the various network elements, which are either Point to Point (PTP), Point to Multi-Point (PTM) or Multi-Point to Multi- Point (MPM) networks. Wireless ad hoc networks can be classified by their application:

- Wireless Mesh Networks (WMN)
- Wireless Sensor Networks (WSN)
- Mobile Ad-Hoc Networks (MANET)

Mobile ad-hoc network is a group of mobile nodes communicating with each other in an infrastructure less environment. The complete routing functionalities is performed by the mobile devices itself. Here the mobile nodes can act as a router for forwarding the data to the next node. The nodes communicate directly within a particular range of radio communications. Mobility is one of the key requirements of the MANET, WMN and WSN

because there the nodes are freely moving in a specific range. For successful data transmission in dynamic mobile based environment, localization is a very important aspect. Once he
movable device location is correctly measured then the later strategies and applications regarding to data transfer and controlling can be developed easily. Because of this feature it is having wide applicability are like disaster relief, military, home and business automations etc. In most of the ad-hoc application, including tracking and monitoring, the location and position is calculated using a beacon signal for position estimates. The position is discovered by measuring the distance or orientation of mobile nodes from some previously located anchor points/beacons or fixed base stations. Now, the position of remaining nodes is calculated based on those beacons. Based on the mechanisms used, localization schemes can be classified into four categories:

- Known Location
- Range-free or proximity-based
- Angle Based
- Range-based.

Usually the above categories can be merged for the same purposes into two prime groups on range based and range free. While proximity-based schemes infer constraints on the proximity to the beacon nodes, range-based schemes rely on the range measurements (received signal strength (RSS), time of arrival (TOA), time difference of arrival (TDOA) and angle of arrival (AOA)) among the nodes. Wireless system requires accurate estimation for emergence services, network monitoring and fleet navigations. TOA location scheme measures the propagation time for a radio wave to travel between the MS and a BS. The AOA scheme utilizes an antenna array and a directive antenna to estimate the direction of arrival signal. However, TOA and AOA methods typically add to the size, cost and energy requirements of each device. The angle-based schemes require a minimum of two BSs to determine the MS location, while the time-based schemes require at least three BSs. However, the time-based schemes generally provide better positioning accuracy than angle-based schemes.

Localization in MANET

The wireless mobile ad-hoc network (MANET) performs the indoor localization using beacon station which emits the signals and receives the signal. Mainly the direction of the signal is calculated. For localization there is a specifically designed criterion by which its evaluation can be performed. Criteria elements are:

1. **Accuracy**: It shows the measurement of reliable location coordinates for the device. Hence the nearest estimate is considered is accurate values.
2. **Precision**: It given the correctness of the detected localization values and very closely related to the accuracy factors. Also the accuracy gives the distance based errors and the precision gives the derivation of generated distance error values.
3. **Coverage**: It shows the distance based measurement covering the region of localization. Mainly it depends on the device types, if the device and its range is small then the coverage is minimum and if the devices are of bigger range and configurations than its range is very large.
4. **Update interval**: It shows the time frequency for processing the updates of location change. But somewhere it affects the power requirements of the device, if the updates are very frequent then required power for this instruction processing is high, and if the interval is high then the power requirements is low.
5. **Computational cost**: The computational cost is an important criterion for evaluation a localization method. More computational cost means more power consumption and more cost on user device.
6. **Infrastructure**: Whether it needs to build extra infrastructure for the deployment of the system or not is import to the budget cost. The reuse and maintenance of the infrastructure is also significant for the deployment. The infrastructure cost also include the user device cost
7. **Off line Computing**: Some of the indoor localization methods requires off line computing or site survey which need labour-intensive work and more deployment time. Such requirement increases the cost for deployment as well as maintenance cost. The off line computing needs to recalibrate every other interval to keep the accuracy maintained.
8. **Localization time**: The time needed for localization for wireless based localization varies for different methods. For methods that support localization for immobile object, the localization time can be very fast. It can provide better coverage on the whole building or room. multi path and shadow fading problems effect the accuracy of localization using wireless signal.

I. BACKGROUND

In recent days the technology advancements is affecting the human lives. Out of those the wireless medium evolution will play the most crucial role is device technologies. They will contribute towards smart cities,

environmental friendly atmosphere, disaster management, military surveillance and next generation services. This information and wireless technologies are becomes more useful if they get tagged with their location information. Mobile ad-hoc network is having the mobile nodes where the communication guaranteed only if the mobile devise keep in range of network. This could be only made possible if there location information is managed along with quite accuracy. Thus the measuring the nodes location is very important. This process of node location detection is called localization. Localization of nodes in MANET (Mobile ad-hoc network) is a challenging and complicated task. The complexity of the problem increases significantly when both the nodes and locating milestone or pivot normally known as the anchors are mobile in nature. Thus detecting the mobile location without any infrastructure elements or additional device such as GPS is a quite typical due to mobility. The key idea behind the approach is to identify the node location regularly during very short span of time. Location updates continuity helps in serving the wireless features in a better way and provides efficient data transfer.

Localization Techniques in MANET

There are several techniques used for location estimation in different environment but there are very few which mathematically detect the position or location and will regularly serve the updates. Following are the three categories of localization:

(i) Proximity

It gives the location on the basis of some previously hosted or located stations or mobile nodes using assumption of their positions. It is range dependent and approximate from the user point of view. For GSM based network of wireless sensor network where the base station or access station are having some fixed locations but in case of MANET there is no such fixed entities thus detecting the proximity based solution is very tedious. Proximity based method has a high variance which sometimes might not satisfy the need for localization. Hence this method no longer appears in recent literatures.

(ii) Triangulation

This technique uses the geometric knowledge and orientation of the mobile nodes. The location of user can be determined by either the distance to the fixed known measurement points, or the received signal angle. It uses the distance and the angle of arrival based information for detecting the current positions and the changing the positions. Suppose we have base A, B, and C, three fixed wireless beacon stations in known positions then it is having two working scenarios:

- ➔ If the distance of the user point to all three base stations is known, the location of user point can be expressed as the intersection of three circles.
- ➔ If the angle of base stations to user point or the angle of user point to base stations is known, it can easily obtains the location of the user point by the intersection of three vectors.

The only problem left is how to get the distance or angle from user point to base points. Triangulation methods are based on angle, time and RSS (Received Signal Strength). It could be further extended to multilateration in which there are three or more than three stations are used for locating the device. IT predictions are based on multiple devices and their difference measurements. But there is associated problem with the triangulation methods is that the beacon and the user node must be in same line of sight.

(iii) Fingerprint

This approach focuses on the characteristic or features of the signal generated specifically from the differentiated devices. In most of the work the RSS technique is used for fingerprinting of the signal. But it made the basic assumption that all the nodes must generate the different signals by which they can be identified individually. By relying on the difference of signals in different position, the current location can be obtained. For fingerprint based indoor localization, there are two different methods: radio-map based fingerprint localization, and map-free fingerprint localization.

This work focuses its intentions towards developing the novel and improved mobile localization mechanism based on the angle of arrival (AoA) and the time of arrival (ToA) with some modified analytical evaluations. Here the angle of arrival (AoA) method calculates the angle of the received signal from the known location or device for position estimation. It can be easily achieved using the directional antennas but are affected from multi-path signals and the reflections from the obstacles or walls. Another approach is time of arrival (ToA) which measures the time of travel between the user devices to the beacon station for assessing the distance between the two nodes. For this the user can transmit the timestamps packet which is received by the beacon device and then the estimation is performed. However, this method assumes that the time in beacon station and user device are the same. To satisfy this

assumption, the stations and user device should precisely synchronize their time which is very hard to achieve in reality. Thus the collaborative approach which includes the feature of both is able to measure the locations of the device more accurately then any single approach. This works aims to show how their functionalities can be combined to get rid of localization problem. Next section of this paper covers some of the previously developed approaches. Later section will give the problem and proposed solution along with their benefits and result factors which affects the localization.

II. LITERATURE SURVEY

During the last few years there are so many approaches developed for improving the localization of the mobile nodes. Even though there are lots of modification needs to be performed more for further getting the accurate results. While drafting this work there are some articles which somewhere relates with this paper are covered here as surveyed literature.

In the paper [7], and hybrid approach for localization is proposed for time of arrival (ToA) and angle of arrival (AoA) using base stations. The scheme also minimizes the impact of non line of sight by calculating the weighted sum of intersection between the given AoA lines and the ToA circles without previous information of non line of sight. Simulation results show that the proposed methods can achieve better accuracy when compare with Taylor series algorithm (TSA) and the hybrid lines of position algorithm (HLOP). It can also be observed that the sensitivity of the proposed methods with respect to the NLOS effect is much less than that for TSA, HLOP. The improvement in location accuracy using the proposed method can also be seen in the CDF curves of the location error.

The paper [8] proposes an approach for AOA estimation in harsh application scenarios and colored noise fields. The approach simulates the uncertain noise covariance as a linear combination of certain known weighting matrices. This process will establish a maximum likelihood (ML) criterion, and a particle swarm optimization (PSO) for optimizing the cost function. Simulation results demonstrate that the paired estimator PSO-ML significantly outperforms other popular techniques and produces superior AOA estimates.

This paper proposes localization algorithm using a hybrid Time of Arrival/Angle of Arrival (TOA/AOA) for Code Division Multiple Access (CDMA) networks [9]. The approach extends the Taylor Series Least Square (TS-LS) technique initially developed for TOA-based systems to integrate AOA assessments. Apart from that the tracking approach utilizes velocity and acceleration calculations. Simulation results illustrate that the proposed TOA/AOA TS-LS can provide better performance than conventional schemes in localization accuracy and in reduce d likelihood of encountering non-convergence problem compared with TOA TS-LS.

Some of the researchers had also worked towards making the localization information more secure along with accuracy. In the paper [10], an attack resistant localization algorithm is redesigned. For secure location estimation there are two major issues, first is the attackers may masquerade as or attack the unknown and anchor nodes to hinder with localization process. Second, the attackers may counterfeit, modify or replay localization information to make the predictable position wrong. Presently, researchers have projected many techniques, e.g., SeRLoc, HiRLoc and ROPE, to solve the above shown problems. This paper describes the common attacks against localization, and gives the detailed survey for secure localization.

The paper [11] gives a brief survey of the Time of Arrival (ToA) ranging method. It often used in the Range-based localization for node distance measurement and prediction of other estimation factors. It mainly deals with Non Line-of-Sight (NLoS) channel identification. One of its dominant factors is that negative affect the location accuracy. It deals with the improvement of the received signal arrival time determination in the case of NLoS communication with undetected direct path. The low complexity NLoS mitigation method is proposed in this paper that estimates the time of arrival of the missing direct path as a mean of the time delays of reflected paths.

Predictive Location Tracking (PLT) [12] is a Kalman filtering formulation based approach in which an added quantity inputs for the location estimator is provided. With the feedback information, adequate signal sources become available for location estimation and tracking of a mobile device. It is shown in the simulation results that the proposed PLT scheme can provide consistent accuracy for location estimation and tracking even with insufficient signal sources.

The paper [13] proposes a new classification scheme for localization technique where range-based schemes and range-free schemes are divided into two types: fully schemes and hybrid schemes. Furthermore, this classification is proposed also to help in comparing localization schemes in terms of accuracy. In particular, between the schemes of the same category either for

range- based or for range- free categories. The paper also analyzes and compare the more representative localization scheme, this comparison was based basically in the following parameters: network assumptions (deployment, Node density, existence of obstacle, existence of anchor node, nodes mobility and mobile assisted), localization process (range estimation, range combination, computational model and localization coordinates), and design goal (scalability, overhead and accuracy).

Several issues relating to security, routing, etc it can be solved if only the actual location of nodes were known. Existing approaches estimate the location of a node in a network by using received signal strength indicator (RSSI), Time of Arrival, Time difference of Arrival and, if directional antennas are available then Direction of Arrival can also be calculated [14]. In these methods the localization accuracy is less (in the order of 20cm). The aim of this paper is to localize nodes in ad-hoc networks with improved accuracy using ultra wide band. The proposed method uses a train of low amplitude pulses of high bandwidth, which reduces the energy consumption, effects due to small scale fading, and dispersion in time and frequency. The network was simulated in NS-2 with UWB extension and the localization accuracy was found to be improved.

In the paper [15], the improvement is suggested for the positioning accuracy of distance vector (DV)-based positioning algorithms, which use angular information DV- angle of arrival (AoA). Here the technique belongs to an ad-hoc localization system. However, the final position estimation is determined by the proposed novel algorithm using only a subset of all intersections. It also assigns the weights to the individual intersections according to their positions and the positions of the RNs. The performance of the proposed enhanced algorithm is verified by simulations and it is compared with the original DV-AoA algorithm.

III. PROBLEM STATEMENT

Mobile devices always suffer with the problem associated with their mobility which causes dynamic change in protocols and the topologies. For getting the movement direction and having the correct estimation about the location of the mobile device there are several localization mechanisms working with MANET. They depend on the coordinates and for estimation the angle of arrival and the time of arrival is the major factor. These factors need to be extensively analysed before deriving some results. In this work we have identified some of the major direction of work which will improve the current localization problems and increases the accuracy to the system.

Problem 1: Al the beacon or anchor nodes placed in MANET is having the Omni directional antennas which was not been able to detect the signals from all the direction hence the localization is made quite complicated over there. This work will suggest a novel positioning which will discover the angle, orientation and the distance of thee node from the anchor nodes.

Problem 2: In mobility based environment the positioning of anchor nodes are not fixed thus we will consider the anchor as a role which can be shifted from one node to other whatever is static at that time and their coordinates are exchanged between other nodes for localization.

Problem 3: Many localization algorithms are sensitive to node density. For instance, hop count based schemes generally require high node density so that the hop count approximation for distance is accurate. Similarly, algorithms that depend on beacon nodes fail when the beacon density is not high enough in a particular region. Thus, when designing or analysing an algorithm, it is important to notice the algorithm's implicit density assumptions, since high node density can sometimes be expensive if not totally infeasible.

We also show that, for the same network configurations (density, number of beacons, number of unknowns, etc), the proposed approach allows more unknowns to be localized (and oriented). This enables some position centric applications—flooding, discovery, or source–sink communication in networks in which global positioning is not available, or necessary. However, TOA and AOA methods typically add to the size, cost and energy requirements of each device.

IV. PROPOSED WORK

This work proposes a novel localization method for mobile nodes position estimation using multilateration triangulation model. The work suggests a range based estimation which requires angle and distance measurement with respect to certain anchor nodes known as beacon.

Localization Model

The range based localization here depends on the relative positions of the neighbour with their geometric positioning algorithms. It could be represented as arbitrary coordinates or an absolute system having uniformity over entire network system. Here the three anchor nodes are used for improving the localization accuracy. The Time of

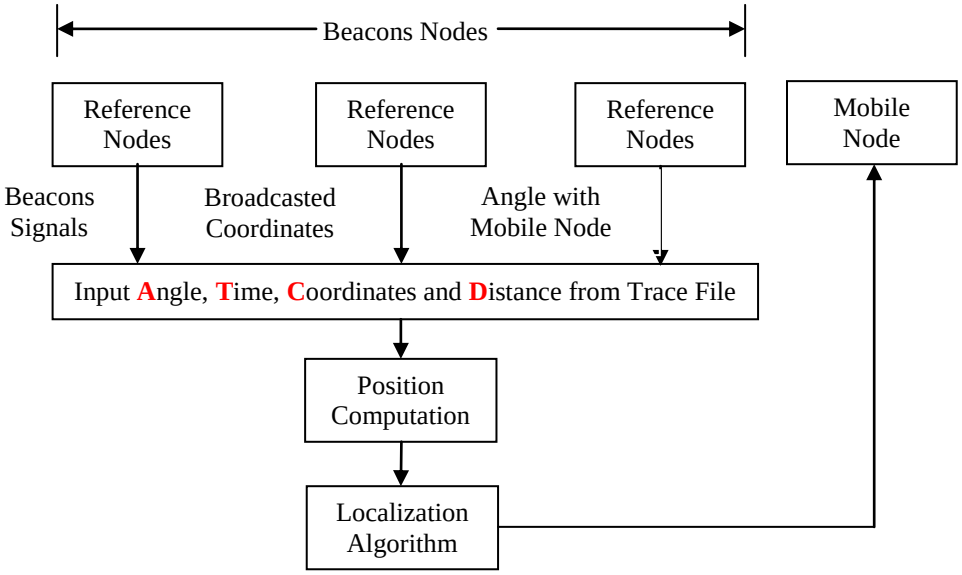

Figure 1: Proposed ATCD Based Multilateration Localization of MANET

Such estimation mechanism in MANET requires dynamic updates because here the nodes are regularly changing their positions cause's unstable topologies. Here the neighbours having already their position devised or calculated can work as the reference nodes. These reference nodes are also known as beacon nodes. They will transmit the beacons signal having initial values of their coordinates, angles along with a timestamp for calculating the ToA. The approach uses multilateration having simplistic principle of trilateration which allows the nodes to estimates their position if they are at just one hop away from the three anchor or reference node. This data is stored I the trace file of the simulator. Now the data is transferred to the positioning node which later on transferred to the localization algorithm. A clear view of approach is been shown in figure 1. As the approach is using the information of angle, time coordinates and distance, thus it was named as ATCD.

Arrival (ToA) and Angle of Arrival (AoA) based positioning scenarios are shown in figure 2 & 3. The Figure 2 shows the ToA calculation using the three reference nodes based range calculation and the distance between them and the mobile nodes are given by R. Thus the square root of the difference in their distance is used for accurate coordinate estimates. Further improvements is here performed by adding angle to it using AoA.

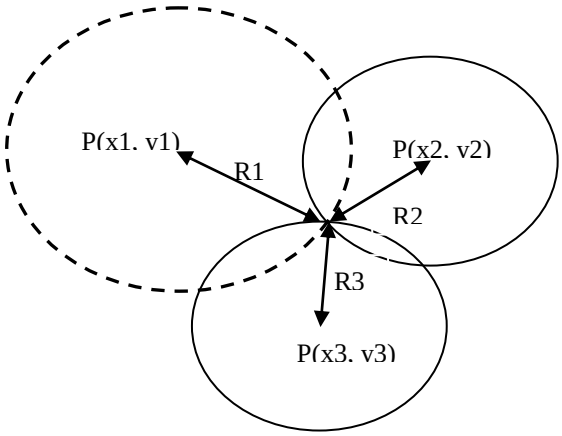

Figure 2: Distance Calculation Using Trilateration Method

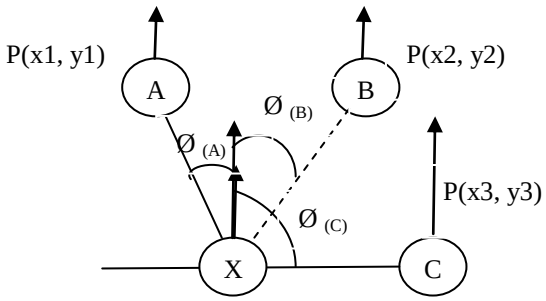

Figure 3: Angle of Arrival (AoA) Calculation Using Trilateration Method

Again it is calculated using three reference or anchor nodes and the calculated angle is mentioned by Ø. For three nodes its three values are calculated.

Let us have a deeper look at the approach. Initially there are three or more reference nodes having their position known using two dimensional coordinates or x and y. The first factor of this work is time of arrival (ToA) which shows the measure of signal propagation time from the sender to receiver for getting the distance estimation between the two mobile devices. In this work the distance is calculated between the mobile node and the anchor node. Here in MANET supports short range radio communication. It shows the distance calculation must be precise and accurate which reduces the burdensome of calculation loads on the mobile nodes. Once the measurement is complete the time can be calculated as:

$$T_{Propagation} = t_{recv} - t_{send}$$

Where the t_{send} is the time of starting transmission and the t_{recv} is the time when the transmission signals are starts receiving. Now on the basis of which distance is calculated. For a time specific range solution distance D between the node m and N is given by;

$$D_{m,N} = S * T_{Propagation\ (m,N)}$$

Here S is the speed of propagation for a specific medium. For MANET it is considered for radio waves. T represents the propagation time for traveling the signal from node m to N. A further expanded view of the above calculation method is the time difference of arrival (TDOA) in which one transmitter/ sender is registered by multiple receivers/destinations. Through a correlation analysis of the received signals, the location of the transmitting station can be obtained. This analysis will require the position of the receivers to be known. sThe calculated and estimate distance errors are given as $E(X_N, Y_N, S)$.

$$E(X_N, Y_N, S) = S * T_{Propagation\ (m,N)} - SqRoot\left[P\left(X_m - X_N\right)^2 + \left(Y_m - Y_N\right)^2\right]$$

The above model is proposed according to the given scenario where three or more anchor or reference nodes estimate the positions. If the number of nodes is gets increased the localization accuracy also gets improved. The method uses distance weighted solution for more closely related values. It works on the basis of trilateration which finds the intersection of the angle and distance of three or more nodes. For measuring the angle of arrival (AoA) receiving signal angle is calculated again from the three nodes and their reference direction (x-axis). It is shown by Θ.

$$\Theta = \tan^{-1}[y/x]$$

Thus by above factor the second goal of angle estimation is also acquired effectively. While evaluating the suggested approach of ATCD it is found that analytically it is showing the positive outputs in different working scenarios. The approach uses multilateration to find the AOA and TOA for mobile location estimation based on their previous calculations. Additionally we provide comparative study between newly designed and previously given technique.

Simulating Setups & Test beds

The suggested protocol will be implemented on the well known network simulator version 2. It sports the ado-hoc routing along with MANET. Now the simulation is devised through some set of steps for ToA and AoA based localization. These are:

(i) Set up the Environment
(ii) Initialize Comprehensive Variables
(iii) Set up topology (Static or Dynamic)
(iv) Configure node (Reference & Mobile)
(v) Give initial Inputs of Angle, Time Coordinates & Distance for mobile & Reference nodes
(vi) Setup traffic flow between nodes
(vii) Implement Distance Weighted Method
(viii) Implement new model
(ix) Tell nodes when the simulation ends
(x) End of simulation

V. EXPECTED OUTCOMES

The localization system is responsible for tracking the device location and estimate its further movement direction based on the certain detection techniques. All it needs is the accuracy ion position coordinates which depends on different network entities and the nodes behaviour. Here the algorithm shares the position estimates between the neighbouring nodes and measured the information available for further improving the previous estimates. It could be an iterative approach which can use multilateration or trilateration for detecting the position coordinates. Here this works aim to improve the estimation based on the angle of arrival (AoA) and time of arrival (ToA). The work handles the iterative nature which reduces the probability of further peculating the error in complete network. Therefore the suppression of position errors at each hop is critical to ensure the accurate localization of all nodes in the network. The below we give some of the benefits of the system:

- It serves improved localization which is not dependent on node density.
- It supports dynamic topology and mobility.
- The approach can be implemented using any of the directional antennas. Thus it removes the dependencies of devices and hardware's.
- At the analytical evaluation the approach is proving its accuracy with multifactor verification.
- Algorithmic measurements derives the low resource consumption
- It is also capable of handling the tight time synchronization of ToA
- It reduces the overhead and delays
- Directional communication links can be used to determine the discrimination angles between nodes relatively easily in ad hoc networks.
- Directional communication systems can increase the total capacity of the network.

Angle based systems can be reduced to trilateration systems (if sufficient information is known) by calculating the distances to neighbours based on the measured angles and some distance information.

VI. CONCLUSION

MANET is a network which depends on the mobility of the nodes hence in such network the topology is changing dynamically. It such type of network localization is the open challenge and research area. There are so many factors on which the nodes performance depends like anchor density, node density, communication cost, accuracy, computational overhead etc. There is so many approaches suggested which are having their own merits and drawbacks, making them suitable for different applications. Mainly the localization is been solved using range based or range free localization. This work emphasizes on range based localization using beacon or anchor node based position estimates. It mainly deals with the angle with references to the anchor node or beacon node. It calculates the position using the trilateration algorithm and updates the position values to the node coordinates. The approach is a beacon based method which requires of a set of nodes, with known locations so the estimation is performed suing their coordinates. The scheme shows its optimal and robust behaviour with a minimum number of beacons in a region for calculation. At the analytical evaluation the promises of independent node density, higher throughput, less overhead and reduced power consumption will add additional benefits apart from accuracy. First the approach is in its development phase and the initial analysis is performed on NS2. For further extension iterative multilateration property can also be included in it.

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