Araştırma Makalesi

RECEİVED SİGNAL STRENGTH BASED LOCATİON ESTİMATİON FOR EMERGENCY CASES

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ABSTRACT

The success of the localization highly depends on the accuracy of the localization algorithm. One of the most well-known and simple localization technique is received signal strength indicator based location estimation which relies on the measuring the power level of the transmitter node. Therefore, in this study, a general framework for the localization of a victim in the harsh environments is given.

Keywords: Received signal strength indicator, localization, emergency situation

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1. INTRODUCTION

Wireless Communications is an essential part of our daily lives. Most of the daily services right now are based on wireless services. Considering the great success of cellular technology, wireless communications seem to be one of the most desired technologies in the near future. Generally, wireless communication is used for voice communications and data communications. In addition, entertainment applications are becoming very popular use of this technology recently. One of the best examples of such applications is gaming and multimedia communications. Although, wireless communication is used for entertainment and daily services, its importance can easily be understood by crucial applications which involve emergency situations. For instance, E-911 applications combined with wireless technology, disaster area communications, public safety and military communications are just to name few. Especially recent unfortunate events such as 9/11, some underground mine disasters, hurricanes, an earthquakes underlined the importance of wireless communication in not only daily use but also in emergency cases.

It is important to note that the evolution in emergency cases is not complete yet. This fact drives the main urge behind the new standards, technologies, and applications. However, the evolution relies on the fact that how vast the wireless technologies can be used in anywhere, anytime. From this aspect, the daily use of wireless depends on mainly the new applications and on new scenarios with the same settings. For example, LTE considers a different access technology for very high speed mobility scenarios in the same environmental classes. However, when emergency cases are considered the situation is quite different. First of all, emergency scenarios include very drastic changes in the propagation environment. Second, most of the times, such environments are not open to public use. Third, the frequency of emergency cases occurring is very low compare to daily applications. One of the best examples of such scenarios is earthquakes and disasters like 9/11. In earthquakes, the environment changes so drastically that communications that are designed for regular use might fail. In 1999, Duzce Earthquake showed that the infrastructural changes required an ad-hoc wireless solution to establish reliable communication in disaster area for very long times. Considering the fact that the devastating impact of earthquake destroyed even the existing infrastructure in the vicinity of entire city which black out the disaster area for very long times. In 9/11, on the other hand, the emergency case was slightly different from earthquake the disaster occurred in daily environment but of a drastic size.

Although the main parts of the infrastructure was still intact, the communication systems still failed due to many other reasons. These two examples show that the importance of wireless communications is of very high level. In addition, different aspects of wireless communications, are seem in different scenarios. In this sequel it is important to mention the use of wireless communications in emergency cases. Most of the applications of wireless communications in such scenarios involve locating victims. This poses a specific concern for wireless communication applications. First, the ultimate purposes to locate victim/victims in the environment with a good accuracy. Second purpose is to establish a communication between the victim and responders. An unfortunate event that took place in Sivas, TURKIYE in which a politician crashed on a helicopter, and unfortunately not be found despite all efforts. This dramatic event showed that even the first step, which is locating the victim, is still problematic in wireless communications community. Note that the major hurdle in these events is time. Timely response will save lives in such occasions. Therefore, not only are wireless applications required to work time but also they are requested to perform faster and better.

2. RELATED WORK

In the wireless community locationing and positioning applications receive a considerable attention. A vast variety of applications are employed based on position information such as E- 911, improved fraud detection, location sensitive billing, traffic management in cellular networks and so on (Caffery, 2000). When the range of the applications are considered locationing has different applications such as inventory tracking, intruder detection, fire fighters and underground mine workers tracking, patient locators and home automation (IEEE 802.15 WPAN Task Group 4). Note also that several standards consider these applications and build some protocols for that purpose such as IEEE 802.15.4a (Amendment of IEEE Std 802.15.4, 2006). A recent application for such a standardization can also be found in the US which is sanctioned by FCC to locate mobile users with a reasonable accuracy for E-911 calls (F. C. Commission, 1996). As stated in (Gezici, 2008) positioning can be established in two different ways which are called "Direct" and "Two-Step Positioning". "Direct Positioning" considers the estimation of target node/victim by directly signals propagating through the environment (Weiss, 2004). However in "Two-Step Positioning", there is an extra step prior to position estimation step, which is called estimation of position related parameters. In this extra step, certain signal estimation. As indicated in (Gezici, 2008) Two-Step Positioning is sub-optimal at the cost of providing lower complexity compared to Direct Positioning (Qi, Kobayashi, and Suda, 2006).

There are several methods employed in positioning algorithms. However, before proceeding further, it is important to define what one understands from the term "Position". Physical position can be either of two types: (a) Absolute position such as WGS, NAD, ED50, (b) Relative position such as 1D, 2D, 3D and 4D (Arslan and Celebi, 2007).

Having said this, in the literature location estimation can be classified by the following three methods:

- Range Based Schemes
- Range Free Schemes
- Pattern Matching Schemes

Range Based Schemes are based on the precise Distance and Angle of Arrival information obtained from the received signal. The statistics of the received signal are obtained by considering several parameters such as Received Signal Strength Indicator (RSSI), Angle of Arrival (AOA), Time of Arrival(TOA) and Time Difference of Arrival (TDOA). For instance, in RSS- based algorithms the power of the signal propagating through environment is considered to carry the distance information between Transmitter and Receiver. This parameter requires the knowledge of several wireless propagation characteristics such as path loss and shadowing to give an estimation about the distance considered (Caffery, 2000). The angle between the two nodes can also be considered as another parameter that carries distance information. Generally antenna arrays or directional antenna use are employed in this method. The main idea behind these methods is to evaluate the angle information of the signal received at different antenna elements and relate this information to distance to be measured (Caffery, 2000; Patwari et al, 2005). Similar to AOA information, TOA information can be used for estimating the distance between victim and receiver. The main idea behind this method is to evaluate the time difference between two signals received at two different locations. However, these methods require a synchronization unit or additional signaling between the nodes of interest. (Amendment of IEEE Std 802.15.4, 2006; Lee & Scholtz, 2002; Lindsey & Simon, 1991) Note that there might be a modification for TOA methods where the synchronization is possible between the reference nodes. In this case the synchronization among the reference nodes, the position estimation can be obtained by evaluating the time differences between the estimates which is known as TDOA (Caffery, 2000). In some techniques, the combination of the parameters considered previously can be merged to obtain better results. These techniques are known as hybrid techniques. Including TOA/AOA (Cong & Zhuang, 2002). TOA/RSS (Catovic & Sahinoglu, 2004), TDOA/AOA (Cong & Zhuang, 2002) and TOA/TDOA (Reza, 2000). Furthermore, some other parameters such as Power Delay Profile (PDP) or Channel Impulse Response (CIR) related parameters can be used to provide position information. (Cong & Zhuang, 2002; Catovic & Sahinoglu, 2004). However, extracting position information from these parameters are very difficult because they require the presence of training phases which is outside the scope of this study due to emergency related cases. In Range Free Methods there are three main schemes which are Hop-Count Based Scheme, Centroid Based Scheme and Area Based Scheme. For further details of such techniques please refer to (Arslan & Celebi, 2007). Another approach found in the literature depends on mapping techniques which require a database in which previously estimated parameters are stored. In this approach, the first step is the calibration of the system based on measurements and statistical characteristics of signal reception at different locations. Generally the largest area is conceptually divided into measurement grids and each corner or node of the grid correspond the measurement data when the real observation is obtained. This observation is compared with previously stored estimates by using some statistical tools such as Bayes-Hidden Markov models. The location estimation is obtained by employing these tools to provide some probability values. The estimation is achieved by choosing the highest probability value that yields the optimum estimate. However, although these methods provide very good options such as learning, building history and error estimation. It has a very major drawback of requiring a database of previous estimations (Ganesh et al, 2005).

Finally, there are also geometric and statistical techniques in the literature that are vastly used worth mentioning at this point. These techniques do not utilize databases. However, they take advantage of several aforementioned parameters a long with some geometrical characteristics related to them. One of the very well-known examples of such techniques is called Triangulation. In this technique, several receivers are employed to capture the signal from the transmitter and by using simple geometrical relationship. A coarse position estimation is obtained (Zeimpekis, 2002). Another example of such techniques is known as Angulation. In this technique, the angles are evaluated in the presence of a relative reference vector. This way, location information can be extracted from the angles of the geometry present in the environment (Zeimpekis, 2002).

Although, its use slightly outside the scope of this study, it is worth mentioning Proximity Based Techniques. In these techniques, several identifiers used for identifying mobile users to the network or the system are employed whenever this identifier is captured by one of the nodes in the system or network that node raises a flag to inform the approximate location of the transmitter. A very well known example of this method is to use Cell-ID information that's being used in cellular systems. When a based station recognizes one of the identifiers the system understands that the transmitter is located in the vicinity of the base stations which raise the flag regarding the reception. Note that such a method can only provide very coarse location information yet, it still provides location information to some extent without employing any extra signaling or unit. (Trevisani & Vitaletti, 2004). Up until this point, some of the very well-known techniques used in locationing applications are reviewed for daily or regular use. However, the problem considered in this study focuses on a very special case of the aforementioned techniques. In the problem considered in this study, the major issue is the emergency case which does not occur very frequently. In addition, when it occurs due to its inherent nature, it takes place very irregular and different environments under very extreme and harsh conditions. These concerns lead to failures when the aforementioned approaches are directly employed in emergency cases. For instance, in 9/11 although the main infrastructure was intact, the effort in locating the victims failed. The robots could not communicate under the rubbles due to very different propagation characteristics which are not found in the literature vastly. Also the earthquake in Duzce showed the same failure scenarios taking place in a different disaster environment. When we look at these two different disaster scenarios one common conclusion can be drawn. The statistical propagation characteristics are quite different in these environments such that directly employing aforementioned method does not even help overcome the communication problem. In this study, I propose an approach which tries to locate a victim whose precise location is unknown but its surrounding environment is known to some extent. More specifically, we consider a disaster scenario in which the victim is surrounded by high mountains or hills, mostly covered by forests under heavy precipitation. The remainder of this study is as follows; First, Statement of the problem is described, then, decentralized and centralized schemes for the problem is studied and lastly, conclusions are drawn.

3. STATEMENT OF PROBLEM

In its simplest form, the statement of the problem can be expressed as follow: A wireless transmitter, which might be a cell phone or another device, is located in an area and actively transmitting some wireless signals. The area is roughly known; However, the exact location of the transmitter is not known. Moreover, in the scenario which will be considered throughout of this study, the transmitter whose exact location is unknown, is assumed to be in mobile, not moving. In this case the purpose is to locate the transmitter by using at least one receiver but most probably more than one receiver. In addition, the evaluation and localization of the transmitter different post processing options can also be considered. In order to generalize the idea presented here, the receivers are assumed to be mobile. The mobility behavior of the receivers is outside the scope of this study.

In order to establish a framework for this challenging problem, the first thing to do is to evaluate the characterization of the signal transmitted by the transmitter whose location is unknown. Since the focus is on radio transmission, the propagation regarding the signal transmission requires the wireless propagation corresponding models. It is known that wireless propagation in different propagation environments differs from each other. Main reason behind this observation lies in the heart of the topographical characteristics of the physical propagation environment. The physical experiments reveal that, as in most of the natural phenomenon the power of the transmitted signal decays very fast with the respect to increasing transmitter-receiver separation. In wireless domain experiments show that the decaying the power is of exponential forms. The characteristics of the exponential decay are determined by the characteristics of the propagation environment. For instance, in an ideal case free space propagation takes place with an exponential factor of two with respect to Transmitter-Receiver separation. However, in most of the propagation environments experiments show that power loss due to separation/distance is greater than two. Note that, in the literature there are some propagation environments in which the exponential decay takes values lower than two. Although this seems controversial, this stems from the behavior of the electromagnetic radiation which can be guided by the environment itself (Rappaport, 2002).

Assume that transmitter to be localized resides in an environment whose topographical characteristics are very distinct. Assume that the transmitter is somewhere within a place which has different mountains of different sizes, most probably in a forest along with heavy precipitation. In this scenario, it is roughly known that the environment in which the transmitter resides are known to the receivers but its exact location is not known. Again, as in the statement of the problem, the receivers tried to locate the transmitter by using the same propagation environment and infrastructural bases.

As illustrated in Figure 1**.,** the specific characteristics of the environment are quite different from the regular, vastly known propagation environment classes in wireless literature. At this point, its worth mentioning that there are different environmental classes in the literature. These classes are important characterize or map relevant propagation models to them.

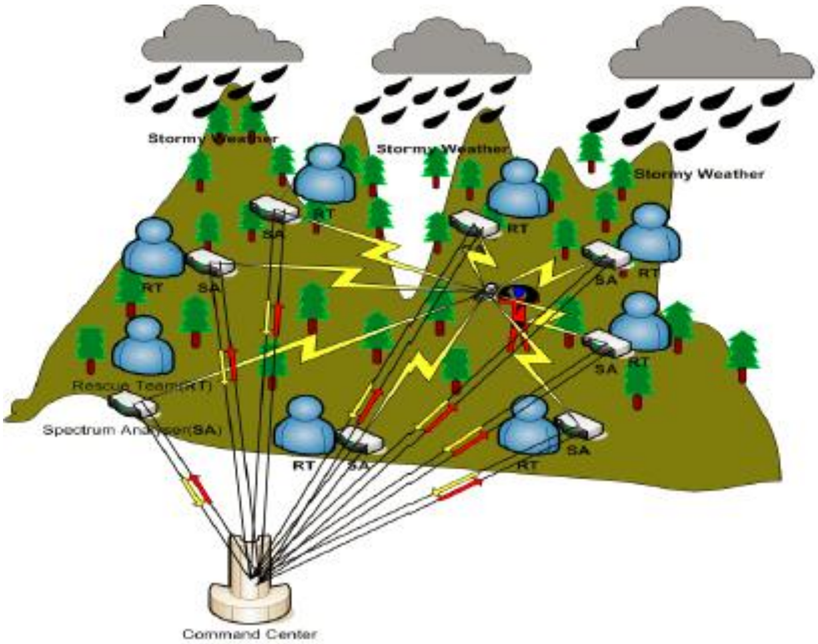

Figure 1. Visualization of Victim Location Scenario.

A classification of well known propagation environments are given in Figure 2**.** Here in figure notice that the classes are well defined and most of them more or less are encountered in the daily life. However, in the scenario considered there are three major environmental characteristics:

- Mountains
- Forest
- Heavy Precipitation
- Depending on the precipitation type snow might be present.

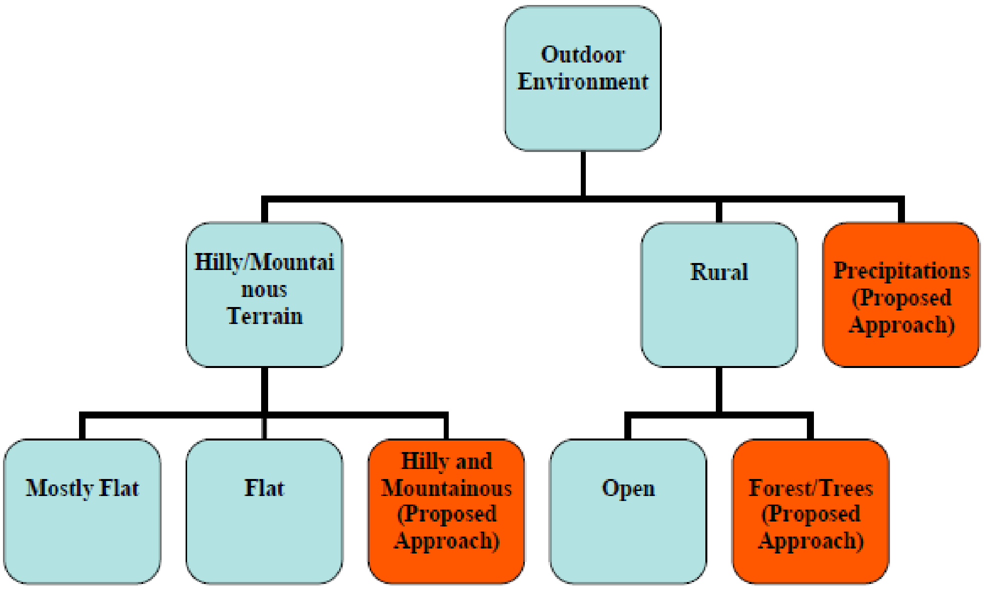

Figure 2. Classification of the scenarios for the victim location.

As compared to Figure 2, such a scenario can not be placed in a very well-known environmental class appropriately. Therefore, there are two ways to approach this problem.

The easiest one but simultaneously most arduous one is to obtain data via experiments in such environments. However, as can be noticed such an approach requires extensive physical effort and working under harsh conditions. In addition, even if the data somehow obtained, it might not be a very good approach from the statistical point of view because such environments are not encountered in daily life. This way, system designers should design for such extreme environments which are not going to provide significant revenue from the marketing perspective. However, experimental data can be seen as the only verification and testing method to rely on in system design.

Since formal models will be employed in system design for even such extreme environments, reasoning and employing statistical/mathematical tools based on induction can be used as a second approach. In this approach, I take the advantage of the models and empirical data existing in literature and exploit the classification that is given in Figure 2 to combine a unified formal model that represents the behavior of the propagation in such extreme environments as close to reality as possible. For instance, in Figure 2 İt can be seen that environments that have trees/forest exhibit a specific pattern in terms of statistical behavior. Similarly areas which include hills/mountain show different characteristics even though it is not in the classification in Figure 2 It is already known that precipitation affects the propagation in an environment drastically. In addition, the existence of snow can also be included into the model as another distinct propagation characteristic. Hence, in the second approach it is aimed that a formal model which has the capability of representing the actual environment as close as possible can be developed by looking at the distinct characteristics of this extreme environmental condition. The statistical propagation model that is related to several classes of the chart given in Figure 2, must be present before proceeding further. However, as can be seen in chart such a one to one correspondence does not exist. Various statistical propagation models for different environmental profiles will be main motivation in deriving a new model that can be used in such new classification.

3.1. Path Loss and Shadowing

Considering the specifications of the scenario in this study first and foremost it is consumed that the transmitter whose location is unknown, is fixed or moving of a very slowly manor. Note that in most of the cases mobility is out of consideration because generally most of the search and rescue operations focus on finding a victim who is not able to move for instance after a disaster or crash. Yet in my scenario the option of slowly moving case can also be considered since it will not change the main reasoning behind the idea. Having said these recalling three basic characteristics of wireless channel, my proposed method will just focus on slow fading characteristics of the signal. Fast fading characteristics can still be observed by the receivers. However, in the proposed method it is assumed that receivers can collect sufficient number of samples to average out the impact of fast fading. Modeling the large scale characteristics in a very accurate way is a difficult task in the absence of experimental data. However, the main behavior in regards to distance-power relationship will be the same with slight modifications. The most important issue in developing model for any type of system is to establish formal framework that is a simple as possible with utmost accuracy. When path loss is considered in this manor the most efficient and simultaneously vastly used model is the linear model. There are plenty of path loss models that are all based on linear relationship between receiver power and transmitter-receiver separation, once the model is selected based on the environment, a relationship between distance and path loss can be shown. One of the most important parameters of these models is known as path loss exponent. In most of the environments the empirical data can be used for acquiring a very accurate path loss exponent value. However, due to the structural difference in physical environments lead to very different path loss exponent values as well. Therefore, rather than sticking with a single path loss exponent value a stochastic approach can adopted to characterize the path loss exponent itself. This way, the path loss becomes a random variable which is governed by a stochastic distribution whose shape relies on different terrain classes. Note that, such an approach would ease my analysis in terms of establishing a generalized framework which include different characteristics such a foliage and precipitation. Furthermore the behavior of path loss exponent can also be characterized by another model since it relies on many distinct characteristics. For instance, in (Hata, 1980) the stochastic behavior of path loss exponent itself is given by another linear model which is dependent on different terrain profiles.

However, it is important to note that such a model still requires empirical evidence to be accepted. In this manner, the path loss exponent in the model proposed can be seen as a Gaussian Random Variable with specific mean and standard deviation pair. Here the main value, of course corresponds to the most frequently accruing path loss exponent in terms of its lightness where as the standard deviation represents how these path loss values are spread. At this point, one should also note that a constant, which is known as intercept, is present in the linear path loss model. However, it is assumed that the transmitter whose location is unknown sends a standardized signal and that signal is of constant power that is well-defined by standard itself. For instance, in GSM specific control channels are used for regulating the transmission for this purpose, by tuning in to those channels can be exploited for this task.

Recall that the loss observed in the received signal is not solely based on transmitterreceiver separation. A significant cause for loss in power is due to the phenomenon called shadowing. It is important to note that the impact of loss due to shadowing is reflected onto the linear model by introducing an additive term. The impact of this additive term again depends on many structural characteristics of the environment. For instance, in the scenario considered here foliage and precipitation are the two main factors of loss because although the transmitter-receiver separation is same, presence and absence of these two factors change the received signal power drastically. Therefore, the linear model is supposed to take this into account in a formal way. The easiest way to reflect the impact of shadowing is to add a random variable into the linear path loss model whose characteristics are based on different environmental characteristics.

In the literature, it is widely accepted fortified by the empirical evidence that's shadowing tends to be of Gaussian form with a specific mean and standard deviation pair. For instance, most of the daily propagation environments exhibit a shadowing loss of a normal distribution on linear scale whose mean is zero with standard deviation of 4 to 12 db (Stuber, 1996). This way we can adopt the same approach in my proposed method to develop my own model. The main issue on this subject is to determine the characteristics of the distribution. The best way to find reasonable values for shadowing is to check literature. Considering, the difficulties in obtaining empirical data in such harsh conditions the values to be employed en the model will be very inaccurate. However, providing a stochastic method for this, the model can be improved. The increasing mean signal power fluctuation become drastic beginning from mild conditions to harshest condition. According to (Lee, 2007) at 240 Mhz, the fluctuation takes 15 dB value from the mean signal strength and comparative analysis shows that this drastic fluctuation stems solely from the weather conditions which include thunder storms and strong winds. From this point of view in my model, it is very likely to expect at least 15 dB of fluctuation around the mean signal strength since the weather conditions are similar. However, it is also known that upper UHF band is more sensitive to attenuation and since in the scenario considered the snow is very likely to be present I expect to have a signal fluctuation which is at least 20 dB or more. Note that in the literature to the best knowledge of author, there is no empirical data available for this specific case.

3.2. Processing the Captured Data

Having stochastic tools in our hand, the next step is to determine how to process the signal captured by the receivers. Depending on the scenarios processing might be of different forms which will be discussed subsequently. In order to appropriately design such a system, communications from node to node or node to another entity in the system requires different settings and design aspects. When the conceptual side of the problem is considered, it is seen that the main classification can be as follows;

- Centralized Schemes
- Decentralized Schemes
- Hybrid Scheme

3.2.1. Centralized Scheme

The main characteristic of this approach is to combine the nodes (receiver capturing signals transmitted by transmitters), communication is established by another unit which is called central switching or central switch. In this case the most important property is to be able to talk to base station by individual bases. However, every transmission has to pass through this switching unit as a direct consequence of this architecture is that nodes are not capable of talking to each other directly. In this scenario, the capabilities of switching unit are very crucial. Generally central switching unit is the common point of interaction between nodes, the place where the main evaluations and calculations are held, governing the important access issues for entire system. The most striking result of this approach is the high computational complex operations are carried out in a single unit rather than several other nodes carrying out the same operations. However, failure of the centralized unit will yield an undesirable situation in which no communication is available between receiver nodes.

3.2.2. Decentralized and Hybrid Schemes

As opposed to centralized approach, the decision can be made by individual receiver nodes based on a structure where node to node communication is possible. In this approach, it is assumed that the receiver nodes are capable of exchange the data between each other. Note that in this scheme, no extra unit is required for seemless transmission. In return the decision is established by the presence of information fed by other nodes, furthermore it might not be possible to convey information from one node to another in wireless domain. Also in a heterogeneous network, the signaling mechanism is going to be different. This forces one to consider other methods. Over the air signaling is suppose to be secure enough especially in the scenario considered. Any unwanted signals with bad intentions might jeopardized the localization operation and lead to a failure in the task. Finally, the information processing regarding the scenario can be in a different format based on the two previous examples. For instance, the most important characteristic of decentralized scheme is not to have an extra unit for node to node communication. On the other hand, decentralized scheme requires additional over the air signaling and is vulnerable to security issues. Therefore, the **Hybrid Scheme** must exploit positive size of the each approach. The first step is to design a system which does not have any extra unit. However, it is also desirable to have information sink in which many bits of information are gathered. Therefore, a node that can be considered as one of the receivers acts as if it is a central switch. Of course, the absence of real switching center must be compensated for by over the air signaling and additional concerns such as security as in the decentralized scheme. Considering all these facts together, in scenarios considered here, it is assume that the rescue teams are equipped with the best available technologies in the market a long with some infrastructural facilities such as satellites. These facilities pave the wave of thinking of the centralized scheme for such a scenario since most of the equipments, techniques, infrastructures and so on are assumed to be given by default.

4. CONCLUSION

We intended to provide a framework for a specific scenario in which localization of a transmitter whose location is unknown but still can roughly be estimated in very harsh conditions such as snow, wind/storms, or heavy precipitations. In the method proposed a statistical model that is based on different distinct environmental classes and corresponding propagation characteristics such as path loss and shadowing are main focus, whereas small characteristics are ignored since averaging out is assume to be employed. Furthermore very slow mobility or no mobility at all is a natural and valid assumption for the scenario considered here. In the model proposed the simplest form of distance dependent path loss is the path loss coefficient. However, due to the variations and distinct characteristics of the environment considered here, the path loss coefficient is considered to be a random variable, rather than a deterministic value. Furthermore, the behavior of random variable can also be modeled again with a simple linear equation which might be dependent on several characteristics of scenario such as terrain structure and foliage. In addition to distance dependent path loss, shadowing is also added into the loss model by introducing an additive term which is again of a random structure. As in path loss fluctuation in shadowing depends on environmental variations such as density of precipitation and its type.

The processing of gathered information is considered to be of centralized scheme because it is assume that the equipments and devices are fully accessorized with recent technology. Having said this, there are very important issues regarding to model proposed;

Unfortunately there is not many empirical data/study in the literature available because of the harsh conditions in the scenario considered. Furthermore such cases are encountered very frequently in daily life. Although in the method proposed can be used for developing a stochastic model. The combined affect of different distinct characteristics is actually an open research problem. The appropriate modeling procedure needs empirical justification. Although centralized scheme seems to be the best decision mechanism, in such environments practicality of this approach is highly questionable. Therefore the deployment of model proposed is another aspect of the problem considered. As a final remark, cognitive capabilities of advanced radios might fuse different environmental characteristics through the use of their artificial intelligence techniques. Neural Networks, Genetic Algorithms, Hidden Markov models and come up with a non-linear model that fits the environment and conditions the best and adapted in a very short period of time. However, testing and verification for these systems should still be a major concern.

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