Location Prediction for Improvement of Communication Protocols in Wireless Communications: Considerations and Future Directions

Abdullah, Sohail Jabbar, Shaf Alam, Abid Ali Minhas

***Abstract*— Location prediction in wireless communication networks is very important and hot research topic in recent times. Location prediction is the estimation of a mobile host's location at a time in future. When the future location of a mobile host is known, this information can be used in a number of ways to improve the performance of the wireless communication network protocols and in turn the overall performance of the network. The hosts are free to move anywhere. This mobility affects different protocols in the wireless communication network. The mobile hosts can move with different mobility patterns. Mobility Models are used to represent the different mobility patterns. Mobility metrics are used to differentiate the mobility models from each other. Different mobility models impact the protocols in different ways. In this paper, the importance of location prediction for improvement of different communication protocols for wireless communications is discussed. Different constituents of location prediction techniques are described. Apart from the conventional mobility prediction techniques, it is concluded that there is a need to look for non conventional solutions like bio inspired systems for making efficient location prediction techniques.**

***Keywords*—Location Prediction, Mobile hosts, wireless communication, MANET**

I- INTRODUCTION

Wireless communication has witnessed great development in recent times. The fast growth in the technology has contributed to this development. Wireless communication networks can be found almost everywhere and have many types. The hosts in wireless communication network can be mobile. In mobile ad hoc networks or MANETs a class of wireless networks, where the hosts are free to connect to the network or disconnect at any time, the hosts like wireless networks should have the capabilities of receiving traffic, processing it, keeping the traffic of interest and sending the unrelated traffic to other devices.

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A MANET generally has the following characteristics [1]:

1. Members can join and leave the network any time,
2. No base station is available for connectivity to backbone hosts or to other mobile hosts,
3. It is difficult to implement sophisticated scheme for handover and location management,
4. Each host acts as a router, forwarding packets from others nodes, and
5. Communication connectivity is usually "weak" in the sense that it is easily broken due to node movement.

With these advancements, need for precise and swift mobility prediction techniques has become very important and gained a lot of attention in current research. Mobility prediction can significantly improve routing, allows estimating the stability of paths in mobile wireless Ad Hoc networks. Many mobility prediction techniques have been proposed in literature. Each mobility prediction technique is based on some mobility model which characterizes the mobility pattern of nodes in a wireless network. Most of the techniques presented in literature use individual mobility models like Random Way Point (RWP) [2], and group mobility models like Reference Point Group Mobility (RPGM) Model [3] etc.. These models are conventionally used for simulation based studies of MANETs, which in some situations fail to realistically represent the movements of nodes in MANETs. Recently the researchers are looking towards non conventional solutions like Bio-inspired solutions for solving problems. Swarm Intelligence is a filed of bio-inspired solutions and describes the collective behavior of birds, ants, termites etc. Swarm Intelligence shows the emergent collective intelligence of simple agents which can solve huge problems in simple and efficient manner. Non-conventional bio inspired Mobility models like Swarm Group Mobility Model [4] and Flocking Mobility Model [5] have been proposed. Swarm Group Mobility Model (SGM) is based on the concept of swarm intelligence. Its characteristics like no permanent membership of a group, a cooperative movement pattern observed in MANETs of military operation and campus etc. suit its application to MANETs and it can realistically represent the movements of mobile hosts in a MANET. The deployment of SGM in MANET simulations is yet to be seen in literature, even though it can be highly useful for development of an efficient location prediction technique in which movements of nodes is represented realistically and their future positions are predicted with maximum accuracy and minimum overhead. In this paper we discuss the

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importance of location prediction for the improvement of protocols in wireless mobile ad hoc networks and the main constituents of location prediction. Rest of the paper is organized as: in section II mobility, its types and effects on communication protocols are discussed, section III, IV and V discuss mobility models, their classification and impacts in MANETs respectively, section VI, VII and VIII discuss location prediction, the need for location prediction and some conventional location prediction techniques respectively, whereas section IX discusses location prediction and its use for communication protocols, conclusion and future work are presented in section X.

II. MOBILITY AND ITS EFFECTS ON COMMUNICATION PROTOCOLS

Mobility in wireless networks means that hosts are free to move in any direction arbitrarily. This free movement of hosts can cause links between hosts to change quite often; the topology is dynamic and unpredictable. Access to information and applications in these freely moving hosts is a requisite for overall working of the wireless network. Creating and maintaining links between mobile hosts is an overwhelming task and a hot research issue in wireless sensor networks. Nodes in a MANET can be static e.g. in many cases sensor nodes deployed do not change their position, the nodes can be mobile and change their position and nodes can be hybrid i.e. can be static at times and mobile at other times. Mobility can be classified on the basis controllability i.e. controlled mobility or uncontrolled mobility and it can also be hybrid: it can be a combination of both. The uncontrolled mobility can further be classified into predictable mobility, unpredictable mobility or combination of both as hybrid. In MANETs mostly uncontrolled mobility is the case and most of the mobility models used in MANETs represent this kind of mobility e.g. Random Walk, Random Waypoint, Reference Point Group Mobility model etc.

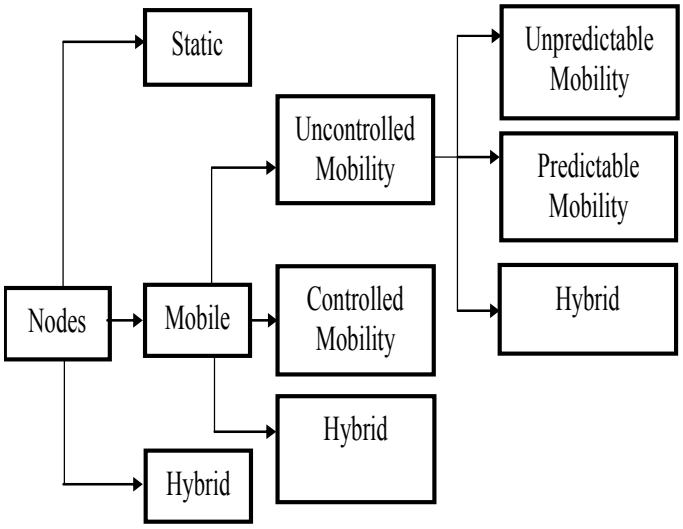

Fig1 Classification of Mobility Based on Controllability[6]

Networking protocols are affected by the mobility of hosts. Mobility has many effects including kink failures, bit error rate degradation, increase in routing overhead etc. In [7] it is shown that as the speed of mobile nodes increases, the number of mobile hosts under any transmission range, probability of a host remaining in a cluster or residence time in a cluster decreases. In [8] two major problem types caused by mobility of nodes are identified and discussed: Lost Link (LLNK) problem and LOOP problem. The LLNK problem is related to the link connection problem with neighboring nodes, and the LOOP problem is related to the inaccurate location information of destination nodes caused by their mobility. In [9] the problems caused by mobility of hosts are identified as route loss, poor longevity of established routes and asymmetric communications links. Mobility of nodes also increases the control traffic overhead and affects the performance of the protocol. A lot of research has been carried out on the mobility induced errors and efforts also made for adapting techniques to minimize these errors.

III. MOBILITY MODELS

The aim of a mobility model is to represent the movement pattern of the mobile hosts in a real MANET realistically. The real mobile hosts can move in any direction with any speed, can move continuously or pause for some time between movements. These different mobility patterns are very important in analyzing the performance of MANETs. Different mobility models try to represent these different and random mobility patterns of real mobile hosts for making a near to real scenario. Mobility models aim to represent mobile host's movement pattern under different network scenarios at different points of time. Mobility models are widely used in simulations of MANETs to analyze their performance. Different protocols are analyzed through simulation for their usefulness and suitability for a specific type of mobile network set up. The role of mobility model is very important in this situation because a mobility model which precisely represents the mobility pattern and characteristics of the real mobile hosts for the specific scenario will be the key for truly examining the usefulness of the protocol for the specific scenario. Several mobility models have been proposed in literature. Some mobility models are conventional mobility models and are widely used for simulations of MANETs in research like the Random Waypoint [2], or Reference Point Group Mobility Model [3] etc., whereas recently new non conventional mobility models have been proposed like the Swarm Group Mobility Model [4] and Flocking Mobility Model [5]. These models are based on the Swarm Intelligence bio inspired solutions. However, simulations of MANETs using these mobility models are rare in literature, and hence the pros and cons of these mobility models remain unknown till reasonable deployment of these models in simulations of MANETs.

IV. MOBILITY MODEL CLASSIFICATIONS

The hosts in a MANET may move independently or more than one host may move in the form of a group. In [10], mobility models are classified into different categories. Mobility patterns can be modeled as Traces and Syntactic/ Synthetic (Fig2): Traces are the mobility patterns of mobile hosts observed actually in a real life system over a period.

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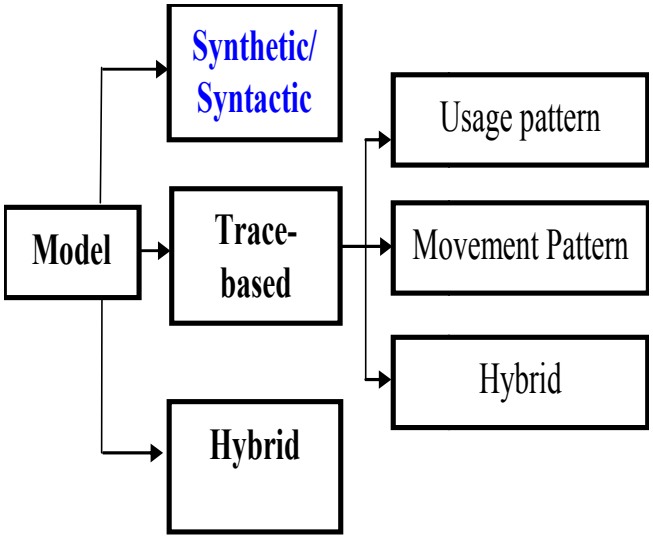

Fig2 Classifications of Mobility Models Based on Model Construction [6]

As they are actual values observed, the values are fully deterministic in the models based on traces. Traces consist of the usage pattern or the movement pattern of the mobile nodes in a MANET or hybrid; a combination of both usage and movement patterns. Traces can be obtained for the systems that are widely deployed in real world, so that actual values can be observed for a long period in these networks, but MANETs are not very commonly deployed in real world and it is difficult to observe traces for the MANETs. Such situations where traces are not available, synthetic also called synthetic mobility models have been proposed and designed to characterize the movement patterns of mobile hosts as closely as possible to the real world e.g. (RWP) [2], (RPGM) [3] etc. The synthetic/syntactic mobility models can further be classified on the basis of randomness, specific mobility characteristics, mobility patterns and histories etc. Figure 3 shows the classification of synthetic mobility models based on randomness as random models and based on specific mobility characteristics [10]: In random models nodes move randomly and based on type of randomness further classification can be made, random waypoint and random walk mobility model are examples. Models with temporal dependency depict the movement patterns that are expected to be influenced by their movement histories, Gauss–Markov and smooth random mobility model are the examples. Models with spatial dependency represent the mobility situations where the mobile nodes tend to move in a correlated manner, reference point group mobility model is an example. Mobility models with geographic restriction represent the scenarios where movements of the mobile nodes are constrained by streets, freeways, and/or obstacles, pathway and obstacle mobility model are two examples. Based on whether the mobility model represents the movement of an individual mobile host or of a group of mobile hosts in a MANET, Mobility models are classified in two categories: Individual Mobility Models also called Entity Mobility Models (EMM) and Group Mobility Models (GMM). In EMM the mobility model tries to predict the movement patterns of individual hosts in a MANET which may work independent of each other.

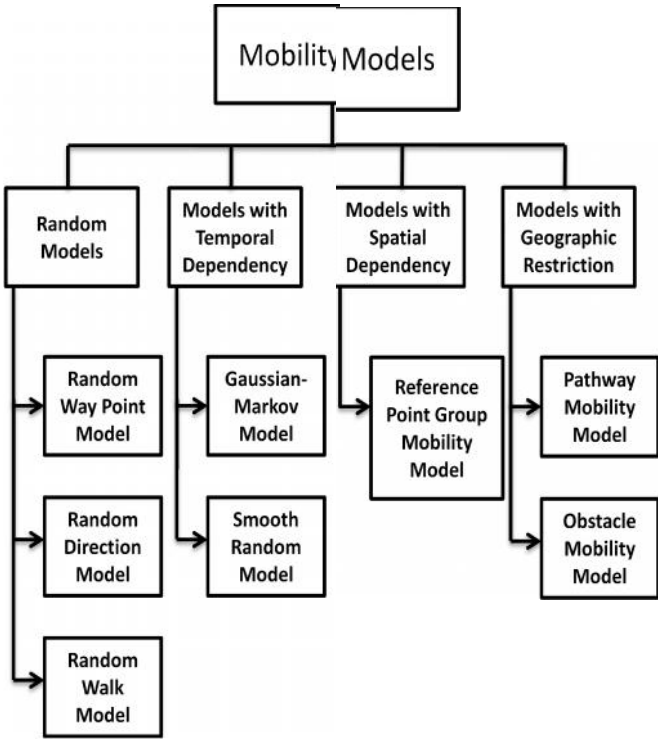

Fig3 Mobility Dimensions & Classification of Synthetic Uncontrolled Mobility Models [6]

In GMM several hosts move in the form of a group, their movements depend on other hosts and they cooperate with other hosts in the MANET. Fig4 shows some examples of EMM and GMM. All these classifications of mobility models are helpful in choosing a proper mobility model for the desired network scenario.

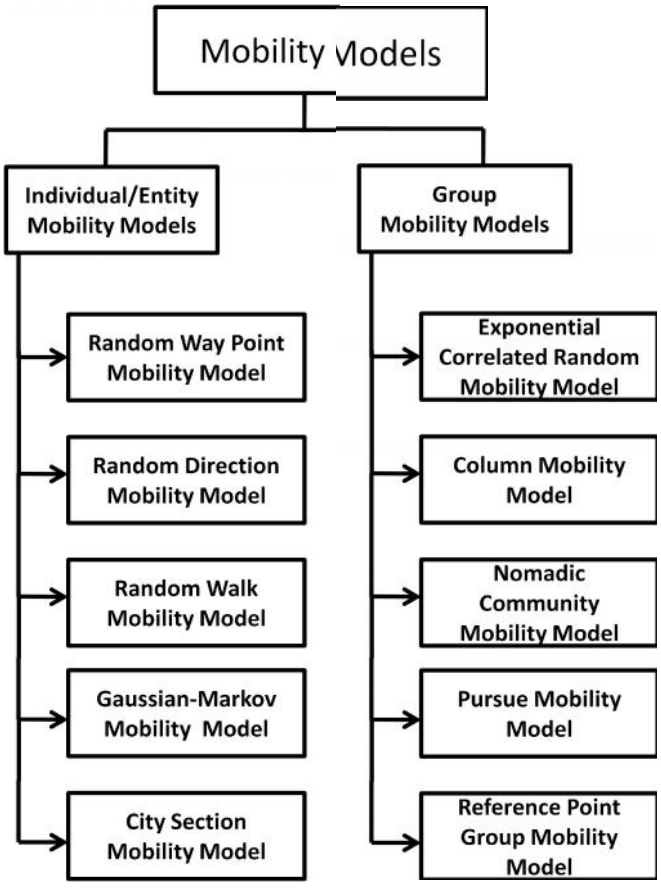

Fig4 Mobility Models Classification

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V. IMPACT OF MOBILITY MODELS ON MANET

The mobility patterns of the mobile hosts influence different aspects of MANETs. Mobility models represent these different mobility patterns and are mostly used in simulations of MANETs. A mobility model cannot represent all possible mobility patterns of mobile hosts in MANETs. Selecting the most appropriate mobility model for the present network scenario is of immense importance. The mobility model should represent the mobility patterns of the mobile hosts for the subject network scenario as realistically as possible, so that the results obtained are accurate and truly represent that network. A lot of work has been done to analyze the impact of mobility models on simulations of MANETs in literature. In [11] Timcenko et al studied performance of different MANET routing protocols with respect to group (RPGM) and entity (RW, GM and MG) mobility models. Simulation results have indicated that the relative ranking of routing protocols may vary depending on mobility model. The proactive protocol DSDV experiences the most stable performance with all mobility models. This protocol performs best with entity models that have lower level of randomness. AODV performs best with the group model RPGM. With entity models, AODV experiences the highest routing overhead with the increase of node speed, but has acceptable average delays. In [12], Yoon et al examined the random waypoint model widely used in the simulation studies of mobile ad hoc networks. Findings showed that this model fails to provide a steady state in that the average nodal speed consistently decreases over time, and therefore should not be directly used for simulation. They showed how unreliable results can be obtained by using this model. In particular, certain ad hoc routing metrics can drop by as much as 40% over the course of a 900-second simulation using the random waypoint model. They also proposed a fix of the problem. Mobility models can be used to test the performance of a specific protocol run in MANET e.g. a routing protocol. The protocol should be evaluated using different mobility models because the performance of a routing protocol changes with the change in the mobility model used. After examining the performance of the protocol under different mobility models, the decision about the effectiveness of the protocol under consideration can be determined.

VI. LOCATION PREDICTION

Location prediction also called mobility prediction of a mobile host is the estimation of position of the host at a future time. The future position of the mobile host depends on several factors i.e. the mobile host can move with different mobility patterns, with variable speeds and in different directions. A lot of Location/mobility prediction schemes have been proposed and designed. Most of these schemes are stochastic and use equations and formulas for the prediction of future location of the mobile hosts. Some of these location prediction schemes are based on the use of history of movements of users. The mobility prediction schemes normally use some mobility model for the representation of mobility patterns of the mobile nodes for the under consideration network scenario. The choice of mobility model impacts the accuracy of prediction results of the mobility prediction scheme. Therefore, for the precise and efficient working of the mobility prediction scheme selection of a mobility model that represents the movement patterns of the real mobile hosts as realistically as possible is a necessity apart from other parameters for the underlying mobility prediction scheme. Most of the location prediction techniques developed are based on conventional mobility models e.g. Random Walk mobility model, Random Waypoint mobility model, Reference Point Group mobility model. These mobility models do not realistically represent the mobility patterns of the mobile nodes in real life systems, especially in the case of MANETs, where nodes can leave or join the network at any time, the topology is dynamic etc. In these situations conventional mobility models fail, and need for non conventional solutions arises. Bio inspired solutions are acquiring interest and success in providing efficient solutions for the problems in different fields including mobility. Recently some mobility models based on the bio inspired solutions like swarm intelligence have been proposed in literature, a Swarm Group Mobility Model [4] based on the concept of swarm intelligence and Flocking mobility model [5] based on the concept of bird flocks in nature. These mobility models are relatively newer and have not been deployed widely for simulations of the MANETs so far, so there is a need to develop a location prediction scheme which uses these mobility models to represent the movement patterns of the mobile nodes in MANETs. Further, these models can be refined and improved through their use in the location prediction schemes as other models like Random Walk, Random Waypoint etc. have been widely used in location prediction schemes for a long period of time and many variants of these mobility models to overcome their deficiencies have been proposed in literature.

VII. WHY LOCATION PREDICTION?

Location prediction in Ad Hoc networks is a very important issue and hot research topic especially because of the enormous advances and developments in the wireless technology in recent times. Knowledge of location is critical to many wireless network applications [13], such as geographic routing, context-aware applications, environment surveillance, habitat monitoring, vehicle tracking, disaster recovery, military reconnaissance and underwater surveillance. Meanwhile, many wireless networks are mobile. For example, wireless devices move with rescuers in a disaster area, move with soldiers in a battlefield, move with tourists in a visitor center, move with animals in a habitat, move with water in the ocean, and move with vehicles around a city. Even sensor networks that used to be static are becoming mobile in order to leverage mobility to efficiently cover a large area using a small number of sensors. It is therefore important to develop effective methods to accurately determine the locations of nodes in mobile networks. Mobility prediction can improve the performance of ad hoc networks in a number of ways; can significantly improve routing, allows estimating the stability of paths, aids in identifying stable paths which in turn improves routing by reducing the overhead and the number of connection interruptions. The importance of mobility prediction techniques can be seen at both the network and application levels. [14] At the network level,

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there are several management tasks that are deeply influenced by the user's mobility. These tasks include handoff management, flow control, resource allocation, congestion control, call admission control, service pre-configuration and quality of service (QoS) provisioning. At the application level, the importance of mobility prediction techniques stems from the Mobile Location Services (MLS), which provide the users with enhanced wireless service based on a combination of their profile and their current or predicted location. Examples of such services are pushed online advertising, map adaptation, user-solicited information, such as local traffic information, weather forecasts, instant messaging for communication with people within the same or nearby localities, mapping/route guidance, and directing people to reach their destination. Location prediction in ad hoc networks can also be used to improve the performance of the routing protocol by predicting the time for which a path and link remains established.

VIII. CONVENTIONAL LOCATION PREDICTION TECHNIQUES

A number of schemes for user movement prediction have been reported in literature. Soh et al. [15] proposed that behavioral information can be used to improve the prediction schemes in situations where knowledge about previous movement history is partially or completely unavailable. The scheme assumes that a user's next move tends to follow the movement pattern of other people in nearby places if they move in the same direction. Ashbrook et al. [16] proposed a scheme which uses a combination of GPS system and Markov model. GPS system collects location information over time. The GPS data is clustered into meaningful locations at multiple scales by the system itself. Then for predicting the future location of the user these locations are then incorporated into a Markov model. N. Marmasse et al. [17] proposed a scheme where first a location model is created from a set of learnt destinations that the user has categorized. Then for the route learning and future route prediction different mobility pattern models, including Markov models and Bayes models are used. Tabbane [18] proposed that the mobile user's quasi-deterministic mobility behavior represented as a set of movement patterns stored in a user's profile can be used to estimate the future location of the mobile user. Liu et al. [19] model the user's movement behavior as repetitions of some elementary movement patterns. A matching/recognition-based mobile motion prediction algorithm (MMP) is used to estimate the future location of the mobile user. In [20] the authors proposed a mobility prediction approach that considers the movement velocity and direction of the MN, and Received Signal Strength (RSS) for accurate prediction of the MN's movement toward a specific access point. Hamid Mehdi [21] proposed a mobility prediction scheme which utilizes GPS location information. In this protocol, GPS position information is piggybacked on data packets during a live connection and is used to estimate the expiration time of the link between two adjacent nodes. In [22] Mohsen et al proposed an offline algorithm to predict the worst-case link durations for MANETs in an urban environment. And based on this prediction, present an efficient routing algorithm which can find more durable paths compared to the shortest path algorithm. In [23] Qin et al proposed Joint mobility prediction (JMP) algorithm with differential accuracy requirements which depends heavily on the cooperation between sink node and sensor node. According to the network application demand, the JMP could reduce the communication overhead between sensor nodes and sink nodes.

IX. LOCATION PREDICTION AND COMMUNICATION PROTOCOLS

Location prediction has been used widely in wireless communication especially in MANETs for improvements in different communication protocols mainly routing. Location prediction is also used for providing quality of service to the mobile hosts. In cellular wireless networks, location prediction models can be used to allocate resources in advance, to assist in handoffs by predicting that the user will move to which base station at a future time, location management, paging, registration, calling time, traffic load [24]. A number of protocols based on mobility prediction have been proposed in the literature. In [25] the authors proposed a new MANET routing protocol called "Location Prediction Based Routing" (LPBR) to simultaneously minimize the number of route discoveries and hop count of the paths for a source-destination session. In [26] a service location and delivery scheme based on mobility prediction is proposed: Mobility aware server selection scheme that can predictive perform server-handoffs necessary for streaming multimedia content delivery is proposed. In [27] a scheme for providing Quality of Service based on predictive mobility is proposed. In [28] a mobility aware distributed topology control scheme in MANETs based on mobility prediction is proposed. In [20] a vertical handover scheme based on mobility prediction is proposed. The proposed approach considers the movement velocity and direction of the MN, and Received Signal Strength (RSS) for accurate prediction of the MN's movement toward a specific access point. In [29] Jian Tang et al proposed reliable routing in MANETs based on mobility prediction. The authors formulate and study two optimization problems related to reliable routing in MANETs. In the Minimum Cost Duration-Bounded Path (MCDBP) routing problem, the authors seek a minimum cost source to destination path with duration no less than a given threshold. In the Maximum Duration Cost-Bounded Path (MDCBP) routing problem, the authors seek a maximum duration source to destination path with cost no greater than a given constraint.

X. CONCLUSION AND FUTURE WORK

In this paper, the importance of location prediction techniques for the improvement of different communication protocols in wireless communication especially in MANETs has been elaborated. The main components for a location prediction scheme have also been figured out and explained. It has been intuited that location prediction schemes are of immense importance for the better performance of different communication protocols and also the overall performance of wireless networks. Although location prediction is a

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relatively new field in research, yet a lot of work has been done in this field. Most of the existing work is based on the conventional methods; there is a need to look into non-conventional methods also: Bio-inspired systems. Biological systems ever provide the better solutions through their intelligent optimization techniques. Swarm intelligence is a main constituent of Bio inspired systems and shows the collective behavior of a large number of simple agents, but the resultant collective behavior shows self organization and decentralized control. The characteristics of swarm intelligence e.g. a flock of birds where a bird can join or leave the flock at any time, there is no centralized control of the flock, each bird in a flock has localized knowledge about its close neighbors and not of all the birds in the flock, these characteristics suit wireless communications especially MANETs which have the same characteristics like a node can join or leave the network at any time, the nodes must have localized knowledge because the nodes are resource constrained. There is need to apply swarm intelligence to develop new location prediction techniques that are best suited to MANETs. In [4] Kim et al. proposed a mobility model based on swarm intelligence namely Swarm Group Mobility Model. Swarm Group Mobility Model can realistically represent the node movement in ad hoc networks. For Future work we propose that there is need to develop a new mobility prediction technique based on the Swarm Group Mobility Model. We hope that it will improve the percentage of correct predictions of node movements as compared to other conventionally used mobility models in MANETs as these mobility models represent the node movements more practically as compared to the other conventional mobility models.

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