# Implementation of MDP over Mobile Ad Hoc Networks

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*Abstract*---We consider the location service in a mobile ad-hoc network (MANET), where each and every node needs to maintain its information about location by 1) often updating its positional information within its neighboring region, which is called neighborhood update (NU), and 2) frequently updating its location information to specific distributed location server in the network, which is called location server update (LSU). The tradeoff between the operation costs in location updates and the performance losses of the target application due to location errors imposes a crucial question for nodes to decide the optimal strategy to update their location information, where the optimality is in the sense of reducing the overall costs. In this paper, we develop a stochastic sequential decision framework to analyze this problem. Under a Markovian mobility model, the location update decision problem is modeled as a Markov Decision Process (MDP). We first investigate the monotonicity properties of optimal NU and LSU operations with respect to location inaccuracies under a general cost setting. From the discovered separation property of the problem structure and the monotonicity properties of optimal actions, we find that 1) there always exists a simple optimal threshold-based update rule for LSU operations; 2) for NU operations, an optimal threshold-based update rule exists in a low-mobility scenario. In the case that no advance knowledge of the MDP model is available, we also introduce a practical model-free learning approach to find a near-optimal solution for the issue.

**Keywords:** S4, BDV, SDV, Control traffic, Packet delivery.

## I. INTRODUCTION

WITH the advance of very large-scale integrated circuits (VLSI) and the commercial popularity of global positioning services (GPS), the geographic location information of mobile devices in a mobile ad hoc network (MANET) is becoming available for many applications. Information about location not only provides one more degree of freedom in designing network protocols, but also is critical for the success of many military and civilian applications, e.g., localization in future battlefield networks and public safety communications . In a MANET, since the locations of nodes are not fixed, a node needs to frequently update its location information to some or all other nodes. There are two basic location update operations at a node to maintain its up-to-date location information in the network. One operation is to update its location information within a neighboring region, where the neighboring region is not necessarily restricted to one hop neighboring nodes. We call this operation neighborhood update (NU), which is usually implemented by local broadcasting/flooding of location information messages. The other operation is to update the node's location information at one or multiple distributed location servers. The positions of the location servers could be fixed (e.g., Home-zone-based location services) or unfixed (e.g., Grid Location Service). We call this operation location server update (LSU), which is usually implemented by unicast or multicast of the location information message via multi-hop routing in MANETs.

## II. DATA ACQUISITION

It is common that there is a tradeoff between the operation costs of location updates and the performance losses of the target application in the presence of the location errors (i.e., application costs). On one hand, if the operations of NU and LSU are too frequent, the power and communication bandwidth of nodes are wasted for those unwanted updates. On the other hand, if the frequency of the operations of NU and/or LSU is not sufficient, the location error will degrade the performance of the application that relies on the location information of nodes. Therefore, to minimize the overall costs, location update strategies need to be carefully designed. Generally speaking, from the network point of view, the optimal design to reduce overall costs should be jointly carried out on all nodes, and thus, the strategies might be coupled. Therefore, a more viable design is from the individual node point of view, i.e., each node independently chooses its location update strategy with its local information.

## III. LITERATURE SURVEY

*Related Work:*

MANETs can be extended to include more design features for the location service in practice. For example, there might be multiple distributed location servers (LSs) for each node in the network and these LSs can be updated independently. A separable cost structure, we show that the location update decisions of NU and LSU can be independently carried out without loss of optimality .Location Servers could not be fixed.Multiple Distributed Location Servers.Multi-hop Routing.

### A. *Survey on Position-Based Routing in Mobile Ad Hoc Networks.*

A Mobile Ad-hoc Network (MANET) is a temporary wireless network composed of mobile nodes, in which an infrastructure is absent. If two mobile nodes are within each other's transmission range, they can communicate with each other directly; otherwise, the nodes in between have to forward the packets for them. In such a case, every mobile node has to function as a router to forward the packets for others. Thus, routing is a basic operation for the MANET. Because traditional routing protocols cannot be directly applied in the MANET, a lot of routing protocols for unicast, multicast, and broadcast transmission have been proposed since the advent of the MANET. This survey gives a thorough study of routing protocols in the MANET.

### B. *Combinatorial Designs in Multiple Faults Localization for Battlefield Networks.*

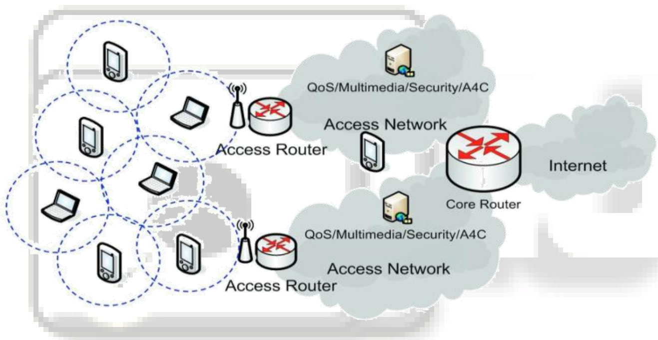
Data-centricity is a feature of wireless sensor networks that distinguishes them from other wireless data networks. Establishing the data as the center of operation in sensor networks provides better usage of the limited resources available in such networks. In addition, data-centricity matches well the nature of wireless sensor networks. This chapter reviews a number of emerging topics collectively constituting a data-centric view of wireless sensor networks.

### C. *Energy and Wireless Link Aware Greedy Packet Forwarding for Wireless Sensor Networks.*

Greedy Packet Forwarding (GPF) algorithm is an attractive localized routing scheme for wireless sensor networks because of its directional routingproperty and scalability. In pure GPF, we add a load balancingmechanism, which is also called an energy-aware algorithm.Based on the energy-aware GPF this paper considers lossy link condition because the choice of high quality link reduces transmission errors.

### D. *A Privacy-Preserving Location Proof Updating System for Location-Based Services.*

Now we look at how they may reveal location information by analyzing the location-proof history. Suppose the attacker has sufficient res




## IV. DESIGN ISSUES

The previously discussed separation property of the problem structure and the mono-tonicity properties of actions are general and can be applied to many specific location update protocol/algorithm design, as long as the conditions of these properties (e.g., a separable application cost structure and a low mobility degree) are satisfied. In this section, we introduce a practically useful learning algorithm—least-squares policy iteration (LSPI) to solve the location update problem, and illustrate how the properties developed previously are used in the algorithm design. The selection of LSPI as the solver for the location update problem is based on two practical considerations. The first is the lack of the a priori knowledge of the MDP model for the location update problem (i.e., instant costs and state transition probabilities), which makes the standard algorithms such as value iteration, policy iteration, and their variants unavailable. 2 Second, the small cell size in a fine partition of the network region produces large state spaces (i.e., S or SNU and SLSU), which makes the ordinary model-free learning approaches with lookup-table representations impractical since a large storage space on a node is required to store the lookup-table representation of the values of state-action pairs. LSPI overcomes these difficulties and can find a near-optimal solution for the location update problem in MANETs.

### *A Learning Algorithm*

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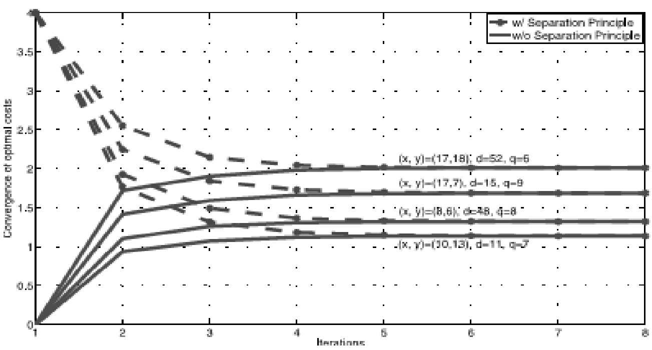
## V. SIMULATION RESULTS

We consider the location update problem in a two dimensional network example, where the nodes are distributed in Least-Squares Policy Iteration (LSPI) Algorithm Strictly speaking; the location request rate is also unknown a priori.

However, the estimate of this scalar value converges much faster than the costs and state transition probabilities, and thus, has reached its stationary value during learning. A square region (see Fig.1) The region is partitioned into M2 small cells (i.e., grids) and the location of a node in the network is represented by the index of the cell it resides in. Nodes can freely move within the region. In each time slot, a node is only allowed to move around its nearest neighbouring positions, i.e., the four nearest neighboring cells of the node's current position. For the nodes around the boundaries of the region, a torus border rule is assumed to control their movements



The specific mobility model used in simulation is

$$P(m'|m) = \begin{cases} 1-4p, & m' = m, \\ p, & m' \in \mathcal{N}(m), \end{cases}$$

Similarly, we also choose a set of 25 basis functions for each of two actions inP2, including a constant term and 24 Gaussian RBFs arranged in a 64grids over the two dimensional state spaceSLSU. In particular,

$$\left\{1,\ \exp\left[-\frac{\|s_{NU}-\mu_1\|^2}{2\sigma_{NU}^2}\right],\ \exp\left[-\frac{\|s_{NU}-\mu_2\|^2}{2\sigma_{NU}^2}\right],\ldots,\ \exp\left[-\frac{\|s_{NU}-\mu_{24}\|^2}{2\sigma_{NU}^2}\right]\right\},$$

The RBF type bases selected here provide a universal basis function format, which is independent of the problem structure. One should note that the choice of basis functions is not unique and there are many other ways in choosing basis functions (see [22], [23] and the references therein for more details). The stopping criterion of LSPI iterations in simulation is set a the performance of LSPI under different traffic intensities (i.e.,

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f) and mobility degrees (i.e.,p), in terms of the values (i.e., feasible overall costs of the location update) at states with using the decision rule obtained from LSPI compared to the optimal values. Both greedy and monotone policy update schemes are evaluated. We also include the performance results of the scheme with the combination of monotone policy update and the upperbounds we observe that: 1) the values achieved by LSPI are close to the optimal values (i.e., the average relative value difference is less than 6 percent) and 2) the 95 percent confidence intervals are relatively small (i.e., the values at different states are close to the average value). These observations imply that the policy obtained by LSPI is effective in reducing the overall costs of the location update at all states. On the other hand, the monotone policy update shows a better performance than the greedy update. The results achieved by the scheme with the combination of monotone policy update and the upper-bounds among all three schemes imply that a reliable estimation on these upperbounds can be beneficial in obtaining a near-optimal solution. Table 3 shows the percentages of action differences between the decision rules obtained by LSPI (with monotone policy update) and the optimal decision rule in different testing cases. We see that, in all cases, the actions obtained by LSPI are the same with the ones in the optimal decision rule at most states (>80 percent), which demonstrates that LSPI can find a near-optimal location update rule.

## VI. TESTBED EVALUATION

We further assess the effectiveness of the proposed model and optimal solution in three practical application scenar-ios, i.e., the location server update operations in well-known Homezone location service and Grid location service (GLS) , and the neighborhood update operations in the widely used Greedy Packet Forwarding algorithm [26], [1]. In the simulation, the number of nodes in the network is set as 100.

### A. *Homezone Location Service*

We apply the proposed LSU model to the location server update operations in Homezone location service .The location of the “homezone” (i.e., location server) of any node is determined by a hash function to the node ID.For comparison, we also consider the schemes, which carry out location server update operations in fixed intervals.

### B. *Grid Location Service*

We also apply the proposed LSU model to the location server update operations in GLS. The locations of location servers of any node are distributed over the network and the density of location servers decreases logarithmically with the distance from the node. To apply our model to GLS, we assume that a location server update operation uses multicast to update all location servers of the node in the network. For comparison, we also consider the schemes, which carry out such location server update operations in fixed intervals.

### C. *Greedy Packet Forwarding*

We apply the proposed NU model to the neighbourhood update operations in Greedy Packet Forwarding. In a transmission, the greedy packet forwarding strategy always forwards the data packet to the node that makes the most progress to the destination node. With the presence of local location errors of nodes, a possible forwarding progress loss happens. This forwarding progress loss implies the suboptimality of the route that the data packet follows, and thus, more (i.e., redundant) copies of the data packet need to be transmitted along the route, compared to the optimal route obtained with accurate location information. As the NU operations introduce control packets, we count the number of control packets and redundant data packets in the network per slot with a given location update scheme. For comparison, we also consider the schemes, which carry out the NU operation when the local location error of a node exceeds some fixed threshold.

## VII. CONCLUSION:

We have developed a stochastic sequential decision framework to analyze the location update problem in MANETs. The existence of the monotonicity properties of optimal NU and LSU operations w.r.t. location inaccuracies have been investigated under a general cost setting. If a separable cost structure exists, one important insight from the proposed MDP model is that the location update decisions on NU and LSU can be independently carried out without loss of optimality, which motives the simple separate consideration of NU and LSU decisions in practice. From this separation principle and the monotonicity properties of optimal actions, we have further showed that 1) for the LSU decision subproblem, there always exists an optimal threshold-based update decision rule; and 2) for the NU decision subproblem, an optimal threshold-based update decision rule exists in a low-mobility scenario. To make the solution of the location update problem to be practically implementable, a model-free low-complexity learning algorithm (LSPI) has been introduced, which can achieve a near-optimal solution. The proposed MDP model for the location update problem in MANETs can be extended to include more design features for the location service in practice. For example, there might be multiple distributed location servers (LSs) for each node in the network and these LSs can be updated independently [1], [13]. This case can be handled by expanding the actionaLSU to be in the set the number of LSU packets and the number of route search packets in the network per slot generated by the scheme obtained from the proposed LSU model, compared to the schemes, which carry out the location server update operations in fixed intervals.

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