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Research Report

Routing in Mobile Wireless Sensor Networks

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I. INTRODUCTION

Wireless Sensor Networks (WSNs) are typically composed of a large number of battery powered and computationally limited nodes deployed over a wide geographic area. In such a scenario, sensor nodes gather useful context information and form temporary ad hoc networks to route the sensed data to one or more collecting nodes (called sinks) in a multi-hop fashion. A sink is usually characterized by higher computational capabilities and less stringent battery constraints with respect to a sensor node and may either be the final data destination (e.g., a user with a PDA or a mobile phone equipped with a WSN interface) or a gateway to a backbone network towards the end-user.

In recent years an increasing interest has been devoted to WSNs with mobile sinks (Mobile WSNs), due to their potential applications. For instance, in [1] the authors consider a system in which multiple users equipped with mobile phones move around a sensor field and interact with the WSN by querying and gathering information of interest. This scenario may apply to environmental monitoring as well as to applications like a store of the future, where a customer receives real time information on his mobile phone being guided through the aisles. Another example of Mobile WSN is provided in [2] for Intelligent

Transportation Systems. In this case, mobile sinks are represented by cars that collect updates on traffic conditions and potential dangers from a WSN deployed in the environment.

Under a networking protocol design point of view, the introduction of sink mobility has two contrasting effects. On one hand, a mobile data collector is able to improve the capacity, the connectivity and the lifetime of the network [3] [4] [5], as will be discussed in Section II-A. On the other hand, mobility makes it more and more difficult to find stable and reliable routes to the sinks without significantly affecting the delivery latency. In fact, routing schemes that are commonly employed in ad hoc and sensor networks, such as AODV [6] or DSR [7], rely on static paths from the data originator to the sink that are extremely fragile to the mobility of the destination. Whenever a route is broken, these protocols react by trying to build a complete new path. This approach significantly increases overhead, with detrimental effects on network performance in terms of latency and energy consumption, [8].

The tradeoffs between the discussed benefits and drawbacks have recently attracted a lot of research on networking aspects for Mobile WSNs. In Section II, we present and discuss in greater detail some of the most relevant works in this area.

II. Related Work

The routing protocols proposed in the literature for Mobile WSNs can be divided in two families. On one hand, some solutions try to take advantage of sink mobility in order to maximize metrics such as energy consumption, network lifetime or connectivity at the expense of delivery latency. We refer to these approaches as *network centric*. On the other hand, some authors have designed protocols that focus on a quick and effective packet delivery to the sink, trying to cope with mobility by adapting classical routing schemes. We refer to algorithms of this kind as *sink centric* ones. In the remainder of this Section, we discuss in greater detail some of the most significant solutions for both the categories.

A. Network-Centric solutions

Network centric solutions stem from the results proposed by Grossglauser and Tse in [3]. In this seminal work, the authors prove how the mobility of nodes can dramatically improve the transport capacity of a wireless network in delay tolerant applications. Transport capacity is defined as the total number of meters per time unit travelled by all the successfully delivered bits . For a network composed of n static nodes deployed over a fixed area, this metric scales as $O(\sqrt{n})$, implying that the average capacity seen by each node decreases with the cardinality of the network as $1/\sqrt{n}$, [9] [10]. This is due to the dominant effect of interference: as the number of terminals increases, only short range communications can reliably take place and packets have to undergo routes composed on average by a larger number of shorter hops. The subsequent increase of relayed traffic has been shown to bound the overall capacity. This analysis suggests as a possible way to improve capacity the idea of exploiting node mobility to reduce the amount of relayed traffic. In [3], the authors propose each packet to undergo at most two hops. If a source node is within communication range of its destination, data are directly delivered. Otherwise, packets are relayed to one of the source's neighbors. The chosen relay caches the packet until its mobility pattern leads it in the proximity of the desired sink, when data are eventually delivered. Such an approach clearly introduces large and unpredictable delays yet the overall network capacity has been shown to linearly scale with the number of nodes (i.e., it is bounded by $O(n)$), with a dramatic improvement over the static scenario.

Transport capacity studies of this kind are typically applied to the design of networks that have to support high traffic rates, due to their hints on effective scheduling policies. However, the discussed solution has recently attracted a lot of interest in the field of routing protocols even for low traffic applications such as WSNs, thanks to its capability of circumventing multihop routes, which are critical to handle in sensor applications due to issues like channel impairments and potentially disconnected topologies. The first attempt to exploit these results in a WSN was proposed by Shah et al. in [5]. The authors consider a three-tier architecture: the lower level is composed by static sensor nodes that generate data; the intermediate level comprises mobile nodes called data MULEs (Mobile Ubiquitous LAN Extensions) and the upper layer is composed by the sinks (which are assumed to be static access points). Data MULEs (or mobile agents) are characterized by large storage capabilities, are assumed not to have stringent energy constraints and are able to communicate via the wireless medium both with sensors and sinks. Examples of mobile agents may be given by a person walking inside a sensor field with a wireless device or by a vehicle moving in a sensor monitored environment. The mobility pattern of a data MULE is typically assumed to be random. The communication scheme is a two-hops one, resembling the one proposed in [3]. Every time a MULE is in the proximity of a sensor, it collects (via one hop communications) and stores all the data that node has generated and cached. On the other hand, when the mobile agent gets close to one sink, it delivers all the packets gathered from the sensor field that are addressed to that sink.

This approach has several advantages, as discussed in [5] and [11]. First of all, the complexity of routing schemes like AODV as well as geographic routing ([12], [13]) is completely avoided, as only one hop communications take place in the network. This leads to a dramatic reduction of the overall overhead, with beneficial effects both on interference and energy consumption. Moreover, the mobile agents may act as bridges in sparse network topologies to enhance connectivity: isolated nodes (i.e., nodes that have no multihop connection to the destination) become able to communicate with a sink as soon as a MULE passes by them and collects their packets. On the other hand, the random mobility pattern of mobile agents, although realistic in some scenarios, may limit the performance of the proposed scheme in terms of delivery reliability and latency. In fact, it may happen that a MULE does not reach some nodes for very long time intervals (especially those close to the border of the sensor field). If such a condition occurs, data may experience intolerable delays or sensor nodes may even have to drop part of the generated packets do to the limited size of their cache.

A slightly different approach has been proposed by Petrioli et al. in [11]. In this work, the authors consider a two-tier architecture, composed by static sensor nodes disposed over a regular grid and by mobile sinks. As opposite to the MULEs scheme, sink mobility is assumed to be controlled[1]. In particular, a destination node moves within the sensor field from one position to another, and stands at one location for a variable sojourn time. Moreover, communications between sources and sink are performed in a multihop fashion: a sensor node sends out gathered data even if the destination is not in the close proximity. This strategy is meant to limit the high latency that characterizes the MULEs architecture. The MAC and network layers considered in [11] are extremely simple for the ease of analytical modelling: nodes generate traffic at a constant rate, one hop communications are assumed to be error free and the routes to a sink are assumed to be always known at every node. Starting from these assumptions, the aim of the authors is to determine the mobility pattern of a sink (i.e., its trajectory and sojourn times) in order to maximize the network lifetime, defined as the time required for the first sensor to deplete its energy. The problem is formulated and solved using linear programming techniques. The identified optimal strategy consists in moving the sink towards regions where the remaining battery energy is higher. This can be explained observing that nodes that are close to a sink experience a high energy consumption, as they have to both serve their own traffic and act as relay for the rest of the network, being the last hop forwarders for most of the routes in place towards the destination. Moving the sink to different regions, thus, averages these effects among the nodes and enhances the performance.

Important improvements are shown in terms of network lifetime with respect to a static sink configuration, as energy consumptionn tends to be uniformly distributed in the sensor field and the advantages offered by the MULEs scheme in terms of connectivity and delivery ratio are confirmed. Moreover, the controlled mobility pattern together with the multihop communication algorithm strongly reduce the latency that affects packet delivery[2].

Although optimal, the discussed solution may not apply to real scenarios, as the assumption of having sink nodes that are constantly aware of the residual energy status of all the sensor nodes is not likely to hold. According to this remark, the same authors have proposed a slightly modified version of this algorithm in [14] [15], with a protocol called Greedy Maximum Residual Energy scheme (GMRE). In this case, some sensor nodes (called sentinels) are selected within the network in a distributed manner[3]. The sentinels periodically gather the battery level of their neighbors using a beaconing system. According to GMRE, a sink remains in the same location for a minimum period and at the end of this interval, it queries the neighboring sentinels in order to get information on the remaining energy for adjacent areas of the

[1]This could be the case of a human or a controlled vehicle moving through the sensor field following a predefined path.

[2]We shall stress, however, that the complexity and the drawbacks introduced by multihop routes are not taken into account into the proposed analysis. The impact of route construction and maintenance procedures may significantly counterbalance the beneficial effects.

[3]The sentinel election process resembles the one that usually takes place to identify a clusterhead.

sensor field. The sink then moves only if the average battery level of one of these regions is higher than the one of the current sink area. If a displacement takes place, the sink moves to the neighboring region with the highest average remaining energy. Such an algorithm can easily be implemented in practice and is shown to incur limited losses with respect to the optimal solution in terms of latency, network lifetime and reliability.

A similar approach has also been proposed by Grossglauser et al. with the MobiRoute protocol in [16]. The authors consider once again a two-tier network with a grid-shaped sensor field and a sink with controlled mobility pattern determined at runtime by means of linear programming in order to maximize network lifetime. The main differences of this work with respect to [15] lie in the fact that a real routing protocol (an extension of MintRouting) as well as a real MAC layer are taken into account. Extensive simulations provide an interesting insight on the practical issues and tradeoffs that rise when such a solution is applied in practice.

In conclusion, *network centric* approaches tend to exploit the mobility of sinks in order to either achieve a better distribution of energy consumption within the network or to simplify the communications scheme for the sensor nodes. Important gains can be obtained in terms of lifetime, connectivity and reliability, thanks to the capacity boost offered by the mobility of data destinations or by mobile agents. However, these schemes incur a high data delivery latency that can only partially be addressed by means of controlled sink mobility patterns.

B. Sink-Centric solutions

Network centric solutions, as discussed in Section II-A, are of interest for applications that tolerate potentially large delays while requiring a long network lifetime (e.g., environmental monitoring). However, WSNs are often used also with different constraints. Let us consider, for example, the *store of the future* application, in which a user equipped with a wireless device moves within a sensor field and interacts with the WSN to receive useful information that guides him through the aisles. In such a scenario, the main objective of the network is to constantly keep track of the mobile sink in order to deliver packets to it in a fast and reliable way. The lifetime of the WSN is not an primary issue, as sensors may be periodically substituted or may even be connected to an external power supply. Applications of this kind require routing protocols that are focused on the requirements of the sink rather than on those of the WSN, hence the name *sink centric* approaches. Many solutions that try to cope with user mobility rather than to exploit it in order to improve the network capacity have been proposed in the literature. Most of them tend to optimize existing routing schemes for ad hoc or wireless sensor networks by exploiting the concepts of clustering and mobility prediction.

An interesting approach has been introduced by Ye et al. in [17]. The authors consider a network composed by a static sensor field with location aware nodes and by one or more mobile sinks with no position knowledge. If routing schemes such as AODV were used, every time a destination joins the network and queries a source, a flooding procedure would be started in order to determine a path from the data originator to the sink. Moreover, the network would often resort to flooding for route tracking due to sink mobility. This would increase overhead and interference, severely limiting the performance, and approaches like geographic routing can only partially address the problem. In order to avoid these issues, the authors propose a two-tier routing. The main idea is to partition the WSN network into clusters, each of them with a clusterhead that knows a route back to the source. Whenever a user enters the sensor field, a local flooding procedure is triggered in order to inform the clusterhead of its presence. This node then forwards the query to the data originator exploiting known routes. The clusterwide flooding is also exploited to build a local route from the clusterhead to the sink. Once the query has been received by the source, the data delivery procedure is initiated following once again a two-tier scheme: packets follow known and static routes up to the clusterhead that in turn has the role to forward them to the sink coping with its mobility. The advantage of this approach is twofold: on one hand flooding messages are kept local and their impact is dramatically reduced (proportionally to the cluster dimensions); on the other hand, if the destination moves within the cluster, only local and quick adjustments to the path have to be made, limiting once again the drawbacks of classic routing schemes.

Let us now consider the proposed algorithm in greater details. In order for the two-tier approach to be effective, it is important that the clustered structure is created before a destination joins the network (otherwise network-wide flooding could not be avoided). To this aim, the authors propose that every time a node starts generating data (i.e., it becomes a source), a clustering procedure is initiated. In particular, the network is partitioned by laying a grid over the sensor field and by letting grid-squares be the clusters. To define such a grid, a source node located at (x, y) identifies the M^2 coordinates of the grid crossing points, (x_i, y_i) with $i = 0, \ldots, M-1$, as $x_i = x + i \cdot L$, $y_i = y + i \cdot L$, where L is the spacing between two aligned points. Each vertex is then associated with a sensor node, that takes the role of head for the cluster corresponding to the adjacent grid-cell (i.e., the grid-cell whose upper-left corner is the the vertex itself). To achieve this association the authors propose an iterative procedure based on geographic packets forwarding. The source node sends out messages containing the coordinates of the four vertexes closest to it (i.e., $x_{\pm 1}, y_{\pm 1}$). Each of these packets is forwarded following the geographic routing paradigm until it reaches the node that is closest to that specific crossing point. Such a terminal is selected as clusterhead and iterates the procedure by computing the coordinates of the three closest grid vertexes (the source is not considered) and sending them out. At the end of the process the grid has been created by identifying the full set of crossing points, also called *dissemination nodes*.

Once this algorithm has been accomplished, the two-tier approach can take place. The traffic to and from the sink is routed through the dissemination node closest to the destination (i.e., the one that has been identified during the local flooding-based association procedure). Routing within the static sensor field (i.e, source to sink associated dissemination node and sink associated dissemination node to source) is performed along the grid lines: data are passed from one dissemination node to another (potentially via multihop) exploiting geographic routing until either the source (upstream traffic) or the sink associated dissemination node (downstream traffic) are reached. On the other hand, packet flows between the sink and the dissemination node associated to it are performed by means of an AODV-like routing algorithm that exploits local flooded messages to build up to date paths.

The algorithm proposed by the authors is called Two-Tier Data Dissemination (TTDD), and summarizes the clustered approach discussed in many other works. Besides the discussed advantages, some drawbacks have to be stressed. First of all, TTDD works well only if few source nodes are present, as otherwise the overhead introduced by the grid construction procedure would override the benefits of localized flooding. Moreover, the idea of forwarding packets within the WSN along the grid lines may generate congestion at some dissemination nodes, especially if the grid is used to distribute data to multiple sinks. This would have negative effects on latency and lead to a very unbalanced energy consumption within the network. Finally, it is important to remark that flooding is not completely avoided and may still have an impact if the sink mobility is fast or if the sink often moves from a cluster to another, triggering new association procedures.

A slightly different approach has been proposed by Abdelzaher et al. with the Scalable Energy-efficient Asynchronous Dissemination protocol (SEAD) in [18]. The authors consider a scenario similar to the one in [17] with location aware static nodes and one or more mobile sinks. The routing procedure is still divided in two phases. As a first step data are routed within the WSN towards a sensor node that is close to the sink. Once such an intermediate destination is reached, a local routing algorithm is run to deliver the payload to the sink. In order to avoid the overhead of flooding based procedures and to prevent the potential bottlenecks of TTDD, the authors try to build a dissemination tree rather than a grid to perform packet forwarding within the WSN. According to SEAD, sensor nodes periodically transmit beacons to inform neighbors of their position. Beacons are used by a mobile sink that joins the network to detect the closest sensor node. Once such a terminal is identified, the sink sends it an association message and forwards to it any data query. The selected sensor node (called *access node*), then, exploits geographic routing to notify the presence of a new sink to the data source. If other mobile sinks join the network through different access nodes and are interested in data generated by the same source, SEAD defines a complete and articulated procedure to create a dissemination tree within the WSN in order to optimize data dissemination for the different destinations (in particular, the tree is built to minimize energy consumption while containing the delivery latency). This approach is shown to offer important improvements with respect to the TTDD solution in terms of network performance, especially when many sinks are present. Once the association procedure is successfully accomplished, the data forwarding starts. The source, as well as the rest of the WSN, identifies a sink with the access node associated to it and packets are routed through the static sensor field via the built dissemination trees (or, if a single sink is interested in data generated by that source, via geographic routing). Access nodes are responsible for tracking the mobile sink and for successfully delivering the payload. This is achieved exploiting the beaconing mechanism rather than relying on the AODV-like solution proposed in TTDD. In particular, let us assume that a sink S is associated to the access node A (i.e., A is the sensor terminal which is closest to S). During its activity, S continues to listen to beacons sent by the surrounding nodes. If a terminal closer to S than A, say B, is found, the sink sends it a message to establish a connection. B, in turn, forwards a packet to A in order to inform it of the new sink position. In this way, the A-B-S route is established. The procedure is iterated as the sink moves along its trajectory, in order to maintain an updated local path with low overhead. The local routing scheme is further refined in order to avoid potential loop conditions and to prevent paths from becoming too long (see [18] for details).

The solutions discussed so far try to cope with user mobility by delegating tracking procedures to sensor nodes that are close to the sink in order to reduce the overall complexity and overhead. This approach mainly stems from the assumption that mobility patterns are completely random. While this may be true for some applications, there are several scenarios in which the user mobility can be predicted with a reasonable approximation. The availability of a trajectory estimation can be exploited to significantly simplify and improve routing procedures. An interesting example of routing schemes that merge mobility prediction and clustering has been proposed by Tacconi et al. in [2]. The envisioned scenario is that of a WSN deployed along a street that gathers environmental information and route it to cars passing by. Under a networking point of view, three types of nodes are identified: Mobile Sinks (MSs), Vice Sinks (VSs) and Sensor Nodes (SNs). MSs (i.e., cars) are assumed to be aware of their current position, trajectory and speed (e.g., being equipped with a GPS locationing system) and are the final data destinations. VSs are those sensor nodes that are in the proximity of the trajectory of a sink (i.e., adjacent to the street). VSs and MSs are able to directly communicate via the wireless medium. Finally, the rest of the sensor network is composed by SN units, which are assumed to be location aware. A MS that enters the network sends out a query containing its id, its speed and trajectory and indicating the region it wants to receive environmental information from. Moreover, a MS periodically transmits beacons addressed to VSs with updates on its position and mobility pattern. When a VS receives a message containing information requests, a query propagation procedure is initiated. The request packet is forwarded by means of geographic routing within the WSN until the SN which is closest to the center of the indicated region is reached. This node takes the role of clusterhead and initiates a local information gathering algorithm, asking (by means of broadcasting) SNs within the specified region to send it data of interest. Once the procedure is accomplished, the clusterhead performs some form of data aggregation and starts forwarding the generated packets towards the MS that requested them. The backward routing procedure within the WSN exploits once again geographic routing, yet the location of the final destination (i.e., the MS) is updated at each hop taking into account the trajectory information contained in the original query[4]. The algorithm stops in one of two conditions: i) a VS receives the packet or ii) a SN does not have any neighbor closer than it to the MS. In the first case, the VS may either be in the proximity of the MS (if the mobility prediction has worked well) or not. If the VS can directly reach the final destination, a one hop transmission is performed and the algorithm successfully terminates. Otherwise, the VS checks if it has recently received beacons from the MS. If this is the case, the MS has already passed by, and is assumed to have surpassed the VS. Therefore, the node initiates a new geographic routing procedure to forward data to the next VS in the direction of the estimated motion for the MS. If, instead, the VS has not heard anything from the sink, it forwards the packet to the previous VS along the estimated mobility pattern (i.e., it assumes that the MS has slowed down its motion). If the algorithm stops in condition ii), geographic routing has lead to a region where no VS is available. In this case, the SN extends the estimated trajectory of the MS and starts forwarding the packet towards the new destination location by means of geographic routing.

The work by Tacconi et al. shows a simple yet effective solution to enhance two-tier approaches like TTDD and SEAD by means of mobility prediction, although the proposed protocol is specifically tailored for a particular application. Many other sink-centric algorithms can be found in the literature for routing in Mobile WSNs, e.g, [19] [20] [21] [22] [23], yet they only introduce slight variations on the main approaches of clustering and mobility prediction and are not considered in greater details here due to space constraints.

III. Conclusions

In this report we have considered the problem of routing in WSNs with mobile sinks. The introduction of non-static data collectors has been shown to bring contrasting effects on the design of networking protocols: on one hand mobile sinks can be exploited to increase network capacity and connectivity at the expense of a higher delay; on the other hand, if delivery latency is a major constraint, routing algorithms that are usually employed in WSNs incur significant performance losses. Starting from these remarks, two classes of solutions, *network centric* and *sink centric* ones, have been analyzed.

The basic principle of *network centric* approaches is to take advantage of the mobility of some nodes in order to simplify the routing procedures. According to these schemes, a sensor node tends to send data only to mobile units (either the sink itself or any other mobile terminal) that are close to it. In particular, if the desired destination is in the proximity of a source, a single hop communication is sufficient to deliver the payload. Otherwise, instead of relying on a multihop path, a source node transmits its data to a closeby mobile user. Such a mobile node stores the received information until its trajectory brings it in the proximity of the final destination, and then delivers the payload. In both cases, only one hop

[4]Let us notice that the prediction is rather easy, as the mobility pattern of the MS is constrained by the street boundaries, which are known by all the nodes in the network.

communications take place in the network and no routing algorithm is required. The use of such routes significantly reduces interference and overhead, leading to important gains in terms of network capacity. Moreover, mobile units moving around the sensor fileld and gathering data are able to enhance the network connectivity, making communications possible also for isolated nodes. Further improvements in terms of throughput and network lifetime can be achieved if the trajectory of some mobile nodes is controllable and optimized. All these beneficial effects, however, come at the expense of a high and unpredictable delivery latency related to the trajectory of the mobile units.

Sink centric solutions, on the contrary, are addressed to scenarios that do not tolerate high delivery delays. The performance of routing protocols commonly employed for applications of this kind is severely affected by the mobility of the sink. On one hand, algorithms such as AODV, that use flooding based procedures to build a multihop path from a source to a destination, experience frequent route failures induced by nodes mobility and have to cope with the detrimental effects of the subsequent route-recovery phases. On the other hand, geographic routing approaches cannot be applied if the location of the final data destination is not known with precision at intermediate nodes, and therefore are not suitable to mobile scenarios. *Sink centric* solutions attempt to address these issues by dividing routing in two phases: as a first step, data generated at a source are forwarded inside the static WSN towards a sensor node close to the mobile sink; once this has been accomplished, a local routing procedure to the final destination takes place. The advantage offered by this approach is twofold. First of all, efficient forwarding procedures like AODV or geographic routing can be exploited during the first phase. Moreover, the paths from the *edge* of the WSN (i.e., the destination of the routing phase within the static network) to the sink are composed by few hops, and therefore mobility can be handled more easily and its drawbacks can be contained. These benefits come at the expense of the procedures required to efficiently identify and maintain routes to a node in the WSN that is close to the final destination. *Sink centric* solutions can be significantly improved if the mobile sink is able to predict its trajectory. In this case, if the information is spread in the network, data can be routed much more precisely towards the exact location of the destination.

In the literature, lots of algorithms have been proposed both for *network centric* and *sink centric* approaches. However, many interesting research directions are still ahead:

- The existing solutions concentrate on networks in which traffic is generated at sensor nodes and has to be delivered to mobile sinks. However, many applications may introduce flows in the opposite direction. This is the case, for instance, of Wireless Sensor and Actuator Networks (WS&ANs). In these scenarios, a user (i.e., a sink) may exploit the gathered information to send back data to nodes within the sensor field in order to let them know how to react to the identified conditions. The traffic from a sink to the static network may have stringent requirements in terms of latency, and therefore specifically tailored routing procedures have to be identified. In brief, networking solutions should not only consider the issue of destination mobility, but also the impact of source mobility.
- The potential of mobility prediction has only partially been exploited so far. Algorithms in the

literature typically assume that a mobile node which is able to estimate its trajectory spreads this information in the network. This approach introduces a potentially large overhead and may not be effective if the mobility pattern rapidly changes. However, in many scenarios the mobility model of a user may be known a priori (e.g., because the movements are limited to certain trajectories and the initial location is fixed). In this case, the sensor nodes may autonomously perform a prediction and exploit it to improve routing without requiring additional traffic coming from the mobile sink. Moreover, if the location of the destination can be effectively predicted within the WNS, geographic routing could be used to perform an end to end data delivery, instead of being used only for data forwarding within the sensor field. This approach may lead to interesting improvements, but also raises new challenges. As an example, if the sink changes its mobility pattern, the rest of the network should be informed of the new trajectory model. Tasks like this have to be optimized in order to limit overhead and interference.

- An integration of *network* and *sink* centric solutions may be interesting and beneficial, in particular in scenarios with multiple mobile nodes and with reliable trajectory prediction models. In this case, mobile units could be used to physically forward information towards the region where the sink is located, reducing the multihop induced overhead while limiting delivery latency.

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