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Determining Minimum Cost Field in Vehicle AD-Hoc Sensor Networks

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Abstract

Vehicle Ad-hoc Network (VANETs) is one of the most promising mobile ad-hoc network technologies that have emerged from the world. In this paper anew cost field based approach is proposed to minimize the forwarding cost by: presenting a new back-off based cost field setup algorithm that finds the optimal costs of all nodes to the sink with one message overhead per node, and once the field is established the message carrying the dynamic information flows along the minimum cost to path in the cost field. As the message travels from the source to the sink, each intermediate node decides to forward the message only if the consumed cost plus the cost at this node (i.e., the minimum cost from this node to the sink) is equal to the source's cost. Otherwise the intermediate node will discard the massage. The correctness and effectiveness of the design is investigated by both simulations and analysis. Energy is used as cost in the simulations.

Keywords: V21, V2V ,VANETs,QoS

Introduction

Wireless Ad-hoc network is a type of networks that have no access point or fixed routers. Vehicular Ad-hoc Networks (VANETs) represent one of mobile ad hoc networks which permit the communication among vehicles, VANETs can operate without any infrastructure or centralized management, the network organization is carried out by the nodes themselves. Every node in VANETS is capable to work at several aspects such as sender, destination or a forwarding node. WSNs are static nodes, while nodes in VANETs can achieve very high speeds. VANETS have the following advantages compared with cellular systems on lower latency due to direct communication, broader coverage and having no service fee. Nowadays, VANETS are a promising solution to traffic management and accidents reduction solution through interchanging the information the driver of vehicle or used to activate an actuator of an active safety system. An example of these applications emergency warning system, lane-changing assistant, intersection coordination, traffic sign/signal violation waning, and road-condition warning [1].The main characteristics that differ VANETs from MANETS are: their high mobility, varying node density, high processing power, movement at high speeds, difficult communication scenarios with short link lifetime [2] . VANETs are formed between vehicles by transmitting and receiving signals with each other, VANETs communication range is limited to one thousand meters in various implementations. Beyond this range the communication of the vehicles is less feasible via high packet loss rate as a result of high mobility. VANETs consist of two basic components. First, vehicle and infrastructures, so they are able to categorized for Vehicle to Vehicle (V2V) and Vehicle to infrastructure (V21) communication [3]. VANETs of routing methods are implemented two aspects, first aspect is Uncast routing by used for two nodes are adjacent and one node sends packets as one to one communication; second aspect is multicast routing one node is used to send data to a group of destinations.

In VANETS all the VANETS nodes or vehicles are moving, so the motion of their nodes or vehicles produces frequent changes in network topology, as well as that the design of routing protocols adeptly to the dynamic environment is a really significant challenging task.

Routing Protocols in VANETs

VANETS characterized by varying network topologies and its dynamic nature routing; these characteristics lead more challenges and complexity of routing protocols. The evaluation of VANETs routing protocols is difficult as VANET prototyping in real time environment is a challenging task, so many researches proposed systematic performance evaluation and comparison of MANET based routing protocols to be used in VANET, they propose to use the QoS metrics for AODV, DSR and ADDMR (Adaptive Demand Driven Multicast Routing) multicast protocols in urban environment evaluation of VANET using [4]. Ad hoc networks use to types of routing protocols: reactive or on-demand routing protocols and proactive or table driven routing protocols [5]. In reactive protocols, the routing table is built on demand by requesting and replies messages; while proactive the routing table is built and updated periodically. In recent years, routing has been a very promising research area in the context of ad hoc networks, and there are many proposals concerned with routing protocols. However, the scale of ad hoc networks is typically much smaller compared with sensor networks, and these proposals typically assume a much smaller network size. These proposals also maintain path states, and require addresses for nodes. Hierarchical proposals may scale with a large number of nodes, but it requires hierarchical address space. Cost has been used in other related work. [6] In this paper Gradient Broadcast (GRAB), GRAB builds and maintains a cost field, providing each sensor the direction to forward sensing data. GRAB forwards data along a band of interleaved mesh from each source to the receiver. GRAB controls the width of the band by the amount of credit carried in each data message, allowing the sender to adjust the robustness of data delivery.
Minimum Cost Forwarding (MCF) protocol was proposed by William D Henderson and Steven Tron [7] to increase reliability in its correctness and study its ability to handle node failure and other errors. MCF is considered particularly appropriate for sensor networks possessing limited resources since it does not require the storage of routing tables at sensor nodes, it establishes optimal routing paths with few message exchanges and it is scalable and simple to implement.

Query-based routing protocol for a WSN that provides different levels of Quality of Service (QoS): energy-efficiency, reliability, low latency and fault-tolerance-under different application scenarios was proposed by [8]. The algorithm has low computational complexity but can dynamically guarantee different QoS support depending on the requirement of the applications. The novelty of the proposed algorithm is its ability to provide multiple QoS support without reconfiguration and redeployment of the sensor nodes.
Vehicular Ad Hoc and Sensor Networks (VASNET) was proposed to highlight the motive in safety on highway roads, since many lives were lost and many more injuries have been occurred because of the car accidents [9]. There are two types of sensor nodes in suggested VASNET, some are embedded in the vehicles (vehicle nodes), and others are deployed in predetermined distances besides the highway road, known as Road Side Sensor nodes (RSS). The base stations may be either stationary or mobile.

Field Based Optimal Forwarding

In this section the procedure followed to establish the field based minimum cost forwarding scheme is presented, by first introduce the cost field concept, and then describe how to use the cost field to realize minimum cost forwarding.

Cost Field Concept

The cost field based design is inspired by a common, natural phenomenon shown in Figure 1: mountain water flows down into a valley and the altitude at each point serves as the guide to direct the water from a high post to a low post, and eventually to the valley's bottom, which has the lowest altitude.

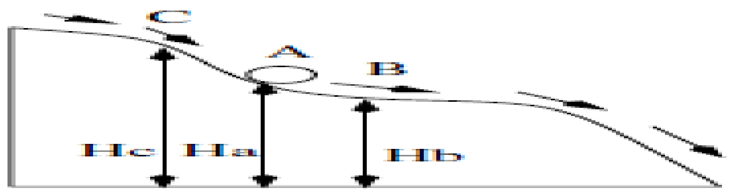

Figure1: Water at Flow Example [10]

Similarly, a cost field is set up. At each node, the cost field is defined as the minimum cost from that node to the sink on the optimal path. The field has only one state at each node. It is the only state kept by each intermediate node. The link cost can take any common form, such as hop count, consumed energy, or delay.

Minimum-Cost Path Forwarding

After establishing the cost field, the minimum cost path is used to forward massages. To eliminate path states, when a message is sent out by a source, it contains the minimum cost from the source to the sink, and the cost consumed so far starting from the source to the current intermediate node. After that the node broadcast this massage to its neighbors without determining any specific neighbor (this is why no IDs are needed for its neighbors). A neighboring node hearing the message decides to forward the message only if the sum of the consumed cost (carried in the message header) and the cost at this node matches the source's cost (also in the message header). Hence, it achieves minimum cost path forwarding without maintaining explicit path information (in terms of which nodes are next-hop nodes along the path) at any intermediate node.
Flooding is originating message at a node and transmitting it via multi-hop to any other nodes in the network. This is a fundamental difference to broadcasting where the message is intended to just the nodes in the direct wireless communication range of the broadcasting node. In general the flooding tries to cover all nodes in the network or a subset of nodes in a geographical area [11]. Flooding is very simple to implement, and it is reactive protocol, as it does not maintain any routing table (topology maintenance) and does not require discovering any routes. But this technique has several disadvantages, the most important being, it is responsible for large bandwidth consumption and it wastes valuable energy. This is not an energy aware protocol also. This protocol is not designed specifically for sensor networks. Similar data produced by nodes in the same region are also flooded, i.e. there is no data aggregation done. The diagram below in figure 2 gives an example for flooding [12].

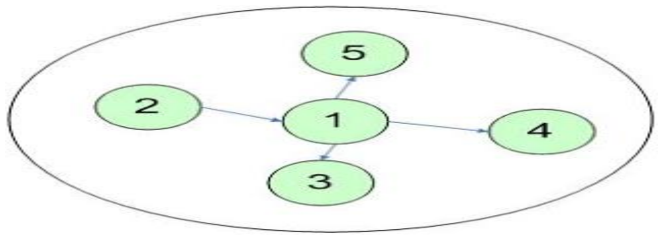

Figure 2: Flooding in WSN

Routing protocols are classified into two major classes: distance-vector routing, and the link-state routing protocol. Distance-vector routing protocols use the Bellman–Ford algorithm, Ford–Fulkerson algorithm, or DUAL FSM (in the case of System's protocols) to calculate paths. A distance-vector routing protocol requires that a router informs its neighbors of topology changes periodically. While, link-state protocols require a router to inform all the nodes in a network of topology changes, distance-vector routing protocols have less computational complexity and message overhead. The term distance vector refers to the fact that the protocol manipulates vectors (arrays) of distances to other nodes in the network. The vector distance algorithm was the original ARPANET routing algorithm and was also used in the internet under the name of RIP (Routing Information Protocol) [13].

A back off-based cost field establishment algorithm

In this approach the broadcast is delayed at the node until it heard the message leading to the minimum cost, the node may broadcast only once, carrying its optimal cost. Thus how long the node defers its broadcast becomes critical. The back off algorithm sets the total deferral time to be proportional to the optimal cost at a node as it is depicted in Figure 3. At time T, node A broadcasts an ADV message and the message is heard by neighbors B and C. Assume the minimum cost at A is LA. The cost for B and C are ∞. After B receives the ADV from A , B sets its cost as LA+1.5 where 1.5 is the link cost between A and B , and B sets aback off timer that expires after γ. 1.5 = 15 where γ is a constant and we let γ = 10. Similarly, C sets its cost as LA+4 and sets aback off timer γ.4 = 40, flooding is used here, so both B and C will broadcast immediately since they have got some costs less than ∞. At T + 15 , B's backoff timer expires , B finalizes its minimum cost as LB = LA + 1.5 , and broadcasts an ADV message containing LB , when C hears it , since LC = LA + 4 > LB + 1 = LA + 2.5 , C updates its cost to LB +1 , and resets its backoff timer to be γ.1=10.

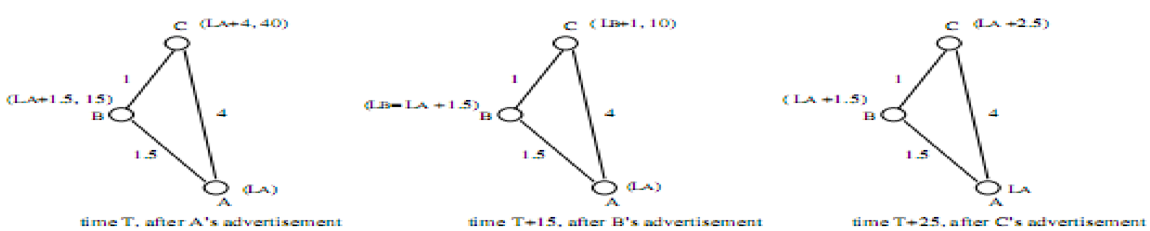

Figure 3: back off-based optimal cost field establishment algorithm [14].

Notice that the previously set timer has not expired by this time. C would advertise a second message at this time. When A receives ADV from B, it discards it since LB > LA. Finally, at T+25, C's timer expires, and C finalizes its cost as LC = LB + 1 = LA + 2.5, and broadcasts a message with its minimum cost. Back-off algorithm assumes no ADV message loss and no delay at nodes, so each node broadcast ONCE and ONLY once, containing its optimal cost (minimum cost field) to the sink and discards all redundant or non-optimal messages. The proof for this property based on that the total back off time is proportional to the minimum cost to the sink, and the nodes broadcast in increasing order of their minimum costs. Figure 4 illustrates this proof.

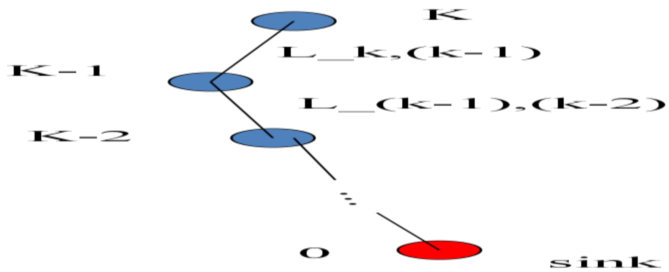

Figure 4: Total back off time proportionality to the minimum cost proof [14].

Proof:-
Total back off time of node K:

$$T_k = T_{(k-1)} + \gamma L_{k,(k-1)}$$
$$= T_{(k-2)} + \gamma (L_{(k-1),(k-2)} + L_{k,(k-1)})$$
$$= \dots$$
$$= T_0 + \gamma \Sigma L_{j,(j+1)}$$

Where:

$j = 0, \dots, (k-1)$

Since $T_0 = 0 \Rightarrow T_k \propto C_k$

Minimum Cost Field Approach

In this approach, a cost field starting from the given sink node is set up, and its value at each intermediate node denotes the minimum cost to reach the sink from that node. As the message travels from the source to the sink, each intermediate node decides to forward the message only if the consumed cost plus the cost at this node (i.e., the minimum cost from this node to the sink) is equal to the source's cost. This way, the minimum cost can be achieved by path forwarding without maintaining explicit path information (in terms of which nodes are next-hop nodes along the path) at any intermediate node. There are some additional goals:

- No forwarding path states are needed; each node only needs to maintain the minimum cost from this node to the sink
- Once the cost field is set up, any sensor can deliver the data to the sink. This is important if the user has interests in observations from multiple sensors – the typical case in a sensor network.
- From the forwarding perspective, each intermediate sensor does not need an ID or an address.

Simulation Setup and Performance Metrics

In the above design, several practical issues have been ignored, these include: delays cannot ignore the effect of transmission, propagation, and processing delays. However, so γ is set large enough to reduce the effect of these delays. Channel errors: In many cases channel is error free cannot be assumed. But among all the successfully delivered advertisements, it can still find the best possible cost field. Node failures: can be reduced by refreshing the cost field either in a time-driven (i.e., periodic) or event-driven (i.e., delivery quality at the sink changes dramatically) manner. To overcome occasional node failures without refreshing the whole cost field, the cost budget at the source to beyond OL_{source} be slightly increased. Thus the message can go along multiple paths and is not subject to node failures along a single path. The simulator is written in mat lab, because of its capability to handle a large number of nodes efficiently. The simulation parameters are written as shown in table 1. The energy cost is used in the simulations. The minimum energy needed to reach another node (that is d ($d \leq 10$) meters away) is d^2 units, i.e., signals attenuate inversely proportional to the square of distance.

Table 1: Simulation Parameters.

Simulator	Mat lab
Number of nodes	Variable (upto1500), randomly-scattered sensors in the area.
Area	Variable(up to $150x150\,m^2$) ,The area is proportional to the number of nodes
Source point	Variable (any selected node)
Sink point (destination point)	Variable (any selected node)
Cost	Energy $\propto d^2$
Link distance	$d \leq 10$ meters
Delay	10 ms
Back-off time constant γ	10 ms

The cost values obtained by a back off algorithm is compared with the cost obtained by flooding, the results show that the minimum costs of the corresponding same node in two cases (back off algorithm and flooding) is exactly the same as the one using flooding. Once the cost field is established, sensor source deliver the data to the sink along the minimum cost path. To this end, each message carries the minimum required cost from the source to the sink, and its consumed cost starting from the source so far to current intermediate node. As the message travels from the source to the sink, each intermediate node decides to forward the message only if the consumed cost plus the cost at this node (i.e., the minimum cost from this node to the sink) is equal to the source's cost.

Message overhead in the cost field setup

The total number of advertisement messages broadcast for five different networks of each group of modes from ten nodes group to ninety nodes group are calculate, the results are shown in Figures 5 and 6. The standard deviation for five different networks of each group of nodes from ten nodes group to ninety nodes group is calculated using alpha value equal to 10% to get the confidence interval of error bar as shown in table 2.

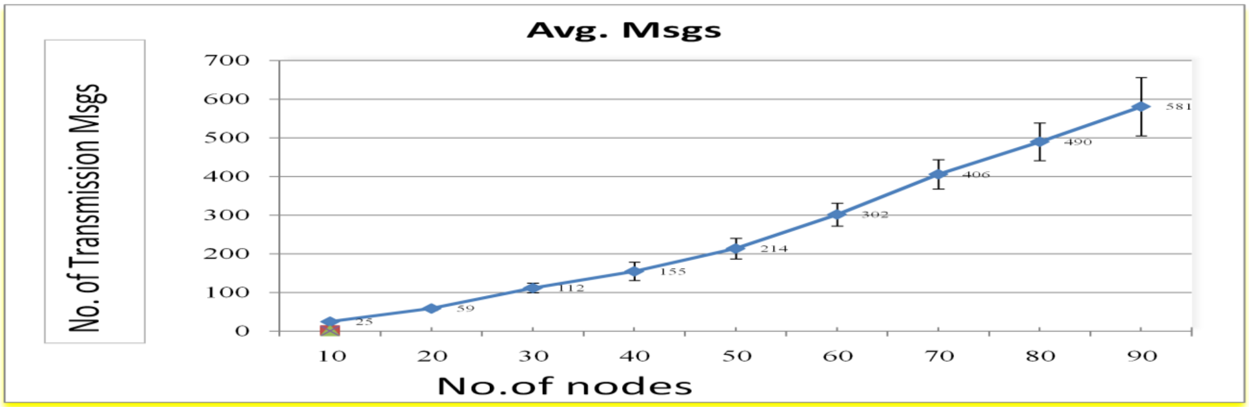

Figure 5: Average messages with error bar using distance vector routing protocol

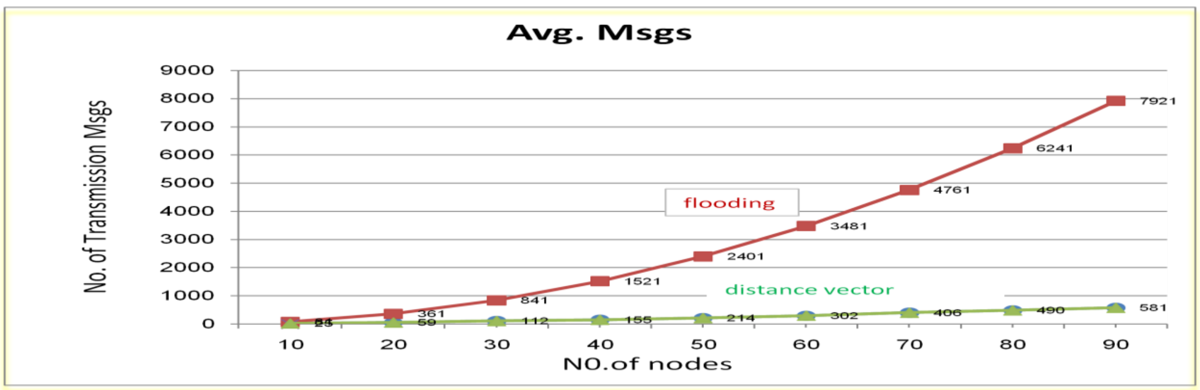

Figure 6: Average messages using a distance vector routing protocol and flooding

Table 2: Parameter of error bar

Standard deviation	interval	alpha
3.63318	2.67257	10%
6.76757	4.97823	10%
17.26268	12.6984	10%
32.33883	23.7885	10%
36.04442	26.5143	10%
40.11484	29.5085	10%
51.79479	38.1003	10%
66.56425	48.9647	10%
102.2458	75.2121	10%

It observed from Figure 5 that, the average messages received increase exponentially as the number of nodes and number of transmission node increase, and the error bar increases as the number of nodes increases. The different of the average number of advertisement messages broadcasts between the distance vector routing protocol and flooding in Figure 6. flooding can easily stress the network and is not scalable because off the average messages broadcast using flooding is very large compare with distance vector routing protocol at the same number of nodes. The average messages broadcast per node for each number of nodes using distance vector routing protocol are calculated and average Standard deviation per node using alpha value equal to 10% to get the confidence interval of error bar to get the results shown in Figure 7.

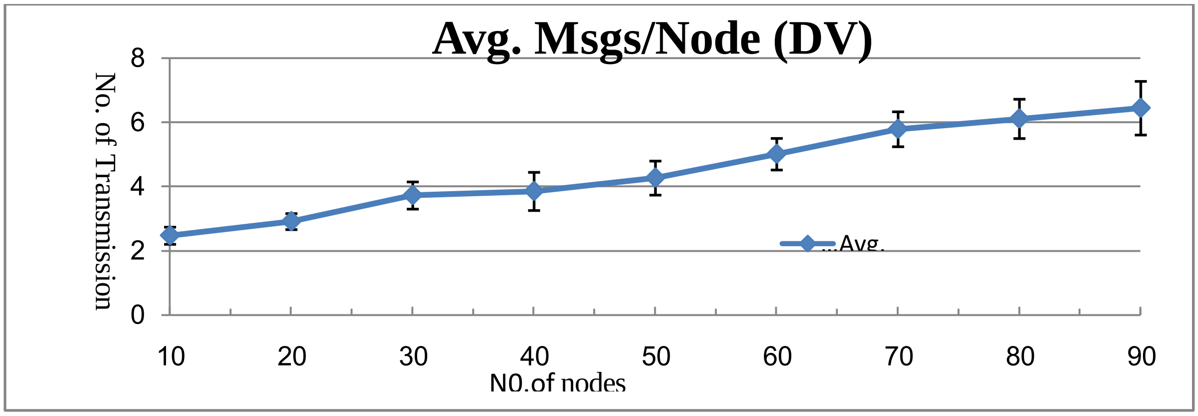

Figure 7: Average messages per node with error bar using distance vector routing protocol

The average messages broadcast per node for each number of nodes using flooding is calculated, to get the average number of advertisement messages per node for each group of nodes as shown In Figure 8.

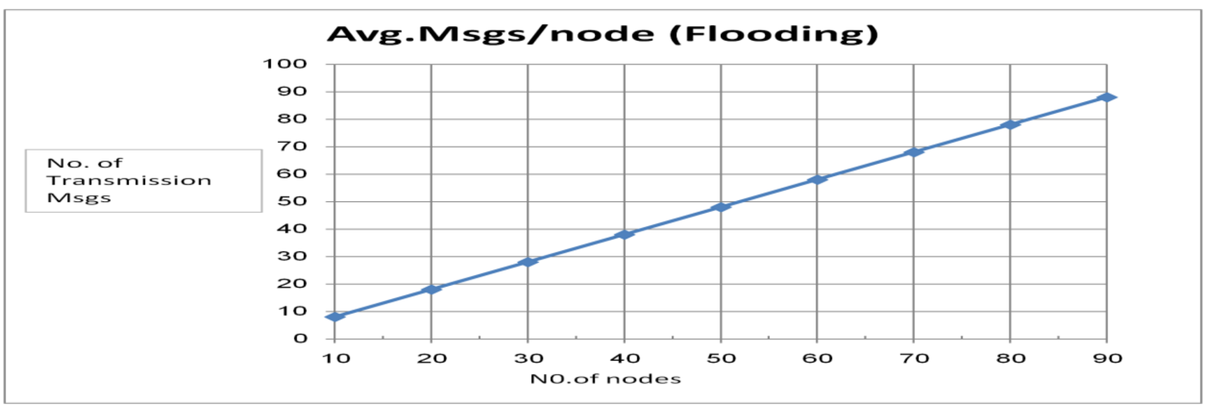

Figure 8: Average messages per node using flooding

It is observed from the above figures that, the flooding based design suffers excessive advertisement messages, a node may receive many advertisement messages consecutively, and each of which leads to a smaller cost. Thus a node could advertise many times. For example, in a network of 15× 15 m^2 area with 90 nodes and a transmission range of 10 meters, the average number of advertisement messages can go as high as 7921 (the average number of broadcasts for each node is about 88.011), but in a distance vector routing protocol it is observed that, the average number of advertisement messages can go as low as 581 (the average number of broadcasts for each node is about 6.453), which is very few compare with flooding.

Conclusion and Future Work

The challenge to deliver messages from any source to an interested client is studied using the minimum cost path in a large sensor network with an unconstrained number of nodes to achieve optimal path forwarding by taking the cost field based approach, this delivery process will be handled in VANETs. A novel back off-based cost field setup algorithm is devised to find the optimal costs of all nodes to the sink with only one message at each node the field is established, the message, carrying dynamic cost information, flows along the minimum cost path in the cost field. Each intermediate node forwards the message only if it finds call self on the optimal path for this message based on the message's cost states. The design does not require an intermediate node to maintain explicit "forwarding path" states. The approach requires constant time and space complexities at each node, as well as scales to large network size.

A new research challenges for providing reliable sensing and robust data delivery via vast numbers of potentially unreliable sensors are appeared, which result in a demand for new solutions to reliable data delivery. Minimum Cost Forwarding Algorithm (MCFA) is an efficient protocol, it invokes an expensive back off algorithm in the setup phase in order to avoid multiple and frequent updates received at the nodes which are far away from the BS

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