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ENERGY OPTIMIZATION IN WIRELESS SENSOR NETWORK USING MOBILE SINK APPROACH

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Abstract: *In wireless sensor network energy is a scarce resource. Concentration of data traffic towards sink causes nearby nodes to deplete their batteries quicker than other nodes, and leaves sink stranded. This problem can be solved by keeping the sink node mobile. Mobile sink saves more energy compared to stationary sink node by moving and collecting information from the field. Existing literature is defined for single mobile sink. Network lifetime can be further increased by multiple mobile sinks in the sensor field. In our proposed work we address this problem for multiple mobile sink. Rendezvous nodes are selected by set covering problem that stores the packets on behalf of network before forwarding to sink at nearest rendezvous point. Sensor network is divided in form of circles that forms the path for mobile sinks. Our scheme increases energy efficiency by reducing hops for forwarding packets. We have also proposed rendezvous node rotation to avoid over utilization of rendezvous nodes. Mathematical formulation is also defined and simulation results are compared with stationary sink and multiple stationary sink. Performance parameters considered are energy efficiency, network lifetime, number of dead nodes and packet drops.*

Keywords: *Wireless sensor network, mobile sink, lifetime maximization, multiple mobile sink, sink mobility.*

I. INTRODUCTION

In recent years, research in wireless sensor networks (WSNs) have emerged as a new information gathering paradigm in a wide spectrum of applications, such as environment monitoring, industrial sensing and diagnostics, battlefield awareness, traffic monitoring, etc. As a result of advancement in microelectronicmechanical (MEMS) and wireless communication technologies, the emergence of tiny sensor nodes has enabled wireless sensor networks (WSNs). Wireless sensor networks are collection of large number of low-cost, low-power and multifunctional sensor nodes that are deployed in region of interest to measure environment conditions or other parameters and forward such information to central point for processing, commonly referred to as sink. These sensor nodes are equipped with sensors, embedded microprocessors and radio transreceivers and therefore have not only sensing capability but also data processing and communication capabilities. Each sensor node communicates wirelessly with other local nodes within its radio communication range and can, in many cases, perform basic computations on data being collected. Distinguished from traditional wireless communication networks, for example, cellular systems and mobile ad hoc networks (MANET) WSNs have unique characteristics and constraints: 1) dense node deployment 2) Battery powered sensor nodes 3) Severe energy, computation and storage constraints 4) Application specific 5) Frequent topology change 6) No global identification 7) many-to-one traffic. This unique characteristics and constraints pose many new challenges in the sensor network design. Communication protocols for conventional wireless networks like cellular systems, wireless local area networks (WLANs) and MANETs do not consider the unique characteristics of sensor networks, particularly the energy constraint in sensor nodes.

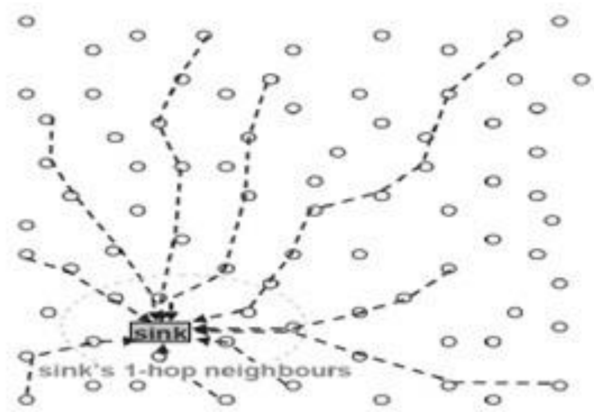

Figure 1 Sensor Network

Therefore, a new suite of network protocols are needed to address various networking issues, taking into account the unique characteristics of WSNs. As discussed above, traffic in WSNs is many-to-one and in most of the applications multi-hop routing is employed in which data is passed from source node to the sink via intermediate sensor nodes, as shown in fig.1.
As a result, there are some serious challenges associated with the use of multi-hop routing, including **Funneling effect:** In many-to-one multi-hop WSN one hop neighbors are required to funnel (forward) data on behalf of distant nodes. As a result congestion starts to build up at sink's one hop neighbors. Consequently, packet drop and/or retransmission become frequent leading to degraded network performance. **Hotspot problem** by being required to forward higher volume of traffic compared to other nodes in network, sink's one hop neighbor called hot spot nodes tends to exhaust their energy and die. This results in compete isolation of sink, resulting in failure of the entire network. So, energy efficiency is most important issue in WSN, as sensor nodes have limited batteries. Therefore routing protocols designed for immobile sinks have to incorporate load-balancing in order to achieve uniform energy consumption throughout network.

A new approach has been introduced that shifts the burden of acquiring the data, from sensor nodes to sink. The main idea behind this approach is that the sink has easily replenishable energy reserves and can easily move within network area, in close proximity to the subset of sensor nodes, collecting recorded data from sensor nodes at low energy cost. Mobile sinks provide load balancing as the hotspot around sink changes as the sink moves and increased energy drainage around sink spread through the network which helps in achieving uniform energy consumption and thereby expand network lifetime. Mobile sinks could even obtain data from isolated portions of the network, which are inaccessible in case of static sinks. Acquiring of data from loosely connected portions of network can be achieved by mobile sink routing protocols with less efforts than static sink routing protocol. Hence sparse and disconnected networks can be better handled by mobile sinks. Sink mobility also reduces number of hops on data routes especially in delay-tolerant applications. It ensures to increase throughput and decrease energy consumption. As the number of transmissions decreases, probability of transmission error and collisions is also reduced. Other advantage of sink mobility is security, as adversary has to locate and chase a mobile s ink carrier to damage sink or retrieve any information. Only the information regarding a small area can be collected by the adversary.

The advantage of sink mobility comes at the cost of advertising the fresh location of sink each time. The overhead included in this operation should not exceed certain limit. The routing protocols designed for WSNs with mobile sink should minimize such overheads and avoid an extreme increase in the sensor data delivery latencies which is not suited for real time WSN applications.

To tackle out the issues associated with mobile sink is the major area of research these days. Due to limited battery unit, protocols are developed to focus mainly on energy saving. Sink mobility is new paradigm in the direction of better energy saving. In this paper we provide survey on existing mobile sink routing protocols.

II. LITERATURE WORK

An efficient mobile sink routing protocol has to fulfill several performance criteria and different applications require maximization of different performance parameters. depending on applications requirement and deployment characteristics sink mobility can be broadly classified as shown in fig.2.

Ming et al.[2] propose data gathering scheme for large scale wireless sensor network and focus mainly on minimizing length of each data-gathering tour i.e. single-hop data gathering problem (SHDGP). A mobile data collector (M-data collector) serves as a "data transporter" to gather data from sensors.

The M-data collector starts tour from the data sink, traverses the network, collects the data from sensors while moving and finally uploads data to the data sink. Main advantage of using M-data collector is that M-collector can visit the transmission range of every sensor, so data can be collected by single-hop communication without any relay. Author also discuss about the problem of finding the shortest moving tour of an M-collector that visits the transmission range of each sensor. Speed of M-collector is assumed to be fixed and clearly by moving through the shortest tour, data can be collected in shortest time. Mathematical formulation is also proposed by author for single hop data gathering problem.

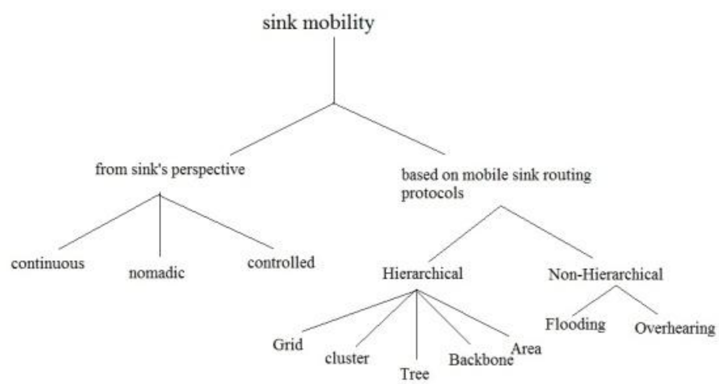

Figure 2 Classification of sink mobility

Authors in [6] have proposed rendezvous point selection scheme (RPSS) in which actor moves from one to other rendezvous point in predefined sequence. Actor node have higher amount of power capacity and memory unit with strong processing unit. As a result it is possible to transfer most of the overhead burden of ordinary node like data aggregation and long distance packet routing at the actor node to increase energy efficiency of the network. Actors in WSNs have to perform two tasks independently: collect the information from the field and act upon the area if event does happen. Actors are randomly deployed in the geographical area hence best actor selection is a challenging task. In [3], authors proposes a novel notation placement pattern that bound time varying routes with the placement of sinks. This technique transforms the problem from time domain into pattern domain and significantly decreases the problem complexity. To bring in the benefits from the sink's mobility, authors in [4] focus on scheduling movement patters of a mobile sink to visit some places in deployed area, to minimize data gathering time. If the tour if sink is not scheduled than message overheads increase as sink announce itself frequents to gather data. Energy consumption involved in flooding control message is high and energy in de-touring the data packets are sent to the previous sink location and then changes to next location of sink. In [4], authors suggest transmitting data via shortest route to the mobile sink's future location. For this, 3 protocols are proposed, sink-trail protocol, sink-trail protocol with multiple mobile sink and sink trail-S protocol. A unique logical coordinate space is represented for tracking mobile sinks.

In [5] authors propose biased sink mobility with adaptive stop times, an efficient data collection method with respect to both energy and latency. Strategy for network traversal, which serves nodes in a balanced manner, is proposed. The traversal is on per region basis: the sink visits regions one after another stopping at each region for appropriate interval to collect data. Sink favors to move less visited and more dense areas rather than frequently visited and sparse areas.

III. PROPOSED WORK

In existing literature sink is assumed to be stationary. When event does happen, sensor forwards the packet to the sink based on cost minimization function. If event occurs far away from the sink position than packet has to travel longer distance which consumes more energy as it is directly proportional to the square of distance. Also sensor node nearer to sink is over utilized and their energy depleted more rapidly which reduces network lifetime. In contradiction to this if sink is kept mobile and allowed to move throughout the field to collect the packets by visiting node, then higher energy can be saved. As there is tradeoff between energy and latency, this approach is not practically realizable. In our proposed scheme we select some nodes called rendezvous nodes. When an event occurs then sensor forward the packet to the nearby rendezvous node which store the packets in its buffer, aggregates them and forward the packets to the mobile sink when it stops momentarily to the nearby location. These locations are called rendezvous points. This scheme involves two parts: selection of rendezvous nodes and secondly selection of rendezvous points which are at the maximum transmission distance R from the rendezvous node. The rendezvous points are selected to reduce the routing distance. Rendezvous nodes are also rotated to reduce the overutilization of nodes. On each path of the sink two rendezvous points are selected randomly. When sink stops at selected rendezvous points nearby rendezvous forwards aggregated packets to the sink. This scheme saves energy to great extent, reduces packet drop rate simultaneously and number of dead nodes. Energy consumption model is presented which shows that total energy consumption is divided in two parts: energy consumed during transmission of packets at some distance d and energy consumed during receiving of packets and also has considered the data aggregation energy consumed by rendezvous node before transmission of packet to sink.

Problem formulation for multiple mobile sink is described below:

$$f = \text{minimize} \sum_{k=1}^{N_1} \sum_{i=1}^{n} \sum_{j=1}^{n} C_{ij} L_{ij}^{K} \qquad (6)$$

Subject to

$$\sum_{K=1}^{N_1} L_{ij}^{K} \le 1 \qquad (7)$$

$$\sum_{K=1}^{N_1} L_{ij}^{K} = 1 \qquad (8)$$

$$\sum_{j=1}^{n} L_{ij}^{K} = 1 \qquad (9)$$

$$U_i - U_j + nL_{ij} \le n - 1 \qquad (10)$$

C_{ij} distance between node i and j 1, L_{ij}^{K} if node i and j are part of sub-path K and 0 otherwise. N_1= total number of sub-paths exist

Constraint 1 defines uniqueness of sink path, Constraint 2 defines uniqueness of incoming link and Constraint 3 defines uniqueness of outgoing link. Constraint 5 defines uniqueness of path and all nodes should be covered.

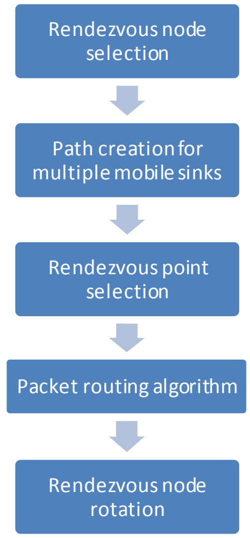

Figure 3 Flow chart for multiple mobile sink

Rendezvous Node Selection

Initially rendezvous nodes are selected using set covering problem. Algorithm for rendezvous node selection using set covering problem is given below:

Procedure rendezvous node selection
initially $S_C = \phi$, $S_U = S$ and $S_A = \phi$
    for each node i **do**
    for each node j **do**
        if d_{ij} < R **then**
            $Net\_set_i \cup$ i
        End If
        if $Net\_set_i = \phi$
            $S_A \cup \{i\}$
      Close
      if no. of members of $Net\_set_i == 1$
        $S_A \cup i$
        $S_C \cup Net\_set_i$
        $S_U - Net\_set_i$
      endif
    end for
    end for
  while S_U is not fully empty **do**
    find the node $S_i \in S$ which has maximum common member between Net_set_i and S_U
    $S_A \cup S_i$
    $S_C = S_C \cup \{S_C \cap Net\_set_i\}$
    $S_U = S_U - \{S_U \cap Net\_set_i\}$

remove S_i from S to avoid repetition.
end while

Path Creation for Multiple Mobile Sinks

After selection of rendezvous nodes, next step is the creation of path for multiple mobile sink. In our work concept of curve fitting i.e. circle fitting is used. It fits a circle to the N points in X minimizing geometric error. Algorithm for Path Creation

1. Select some square area arbitrary.
2. Find rendezvous nodes falling within this area.
3. Pass this nodes for curve fitting to create circle
4. **If** r_i<=d_i then
5. L1=L1-delta
6. w1=w1-delta
7. go to step 2
8. **end**
9. Select outermost square area
10. Select rendezvous nodes between inner circle and outer square and pass it for circle fitting
11. **if** r_i>=d_i and r_i>=d_j
12. go to step 9
13. **else**
14. L1=L1-delta
15. w1=w1-delta
16. Go to step 10
17. **End**

Rendezvous Point Selection

Rendezvous points are selected on the path created for multiple mobile sink. In our work two rendezvous points are selected on each path of mobile sink. One rendezvous point is selected at a point which is at minimum distance from all the rendezvous nodes falling within selected area and another rendezvous point is selected at a point of maximum distance. Sink stops for predefined time at this rendezvous point, rendezvous node within area finds the nearest rendezvous point and routes the aggregated packets to the sink. This procedure is repeated for all the paths of mobile sink.

Packet routing Algorithm

When event occurs source node routes the packet to the nearby rendezvous node. To route the packet, source node selects the best routing node from its neighboring node as explained in algorithm. This process repeats until packet is packet is delivered to rendezvous node or dropped. Packet is dropped if no suitable neighboring node is found. d_{ij} is distance between node i and j. Distance between i[th] or j[th] node and rendezvous node is defined as d_j^{Rendz} d_i^{Rendz} .

Remaining and threshold energy of j[th] nodes is represented by E_{Rem} and E_{th} .

Packet routing algorithm is described below:

if (event does happen) **then**
while packet not reach to rendez node or dropped **do**
create a set of neighboring node of source node
if $d_{ij} \le R$
store those nodes in set S1
if (S1 is not empty) **then**
from all nodes in S1

find closest node to rendez node than source
if $\left(d_j^{\text{Rendez}} \le d_i^{\text{Rendez}}\right)$ **then**
store those nodes in set S2
End If
If (S2 is not empty) **then**
From all the nodes in S2
Find the nodes energy above threshold
If ($E_j^{\text{Rem}} \ge E_{th}$) **then**
Store those nodes in S3
End If
If (S3 is not empty) **then**
From all nodes in S3
Find the single node for which has ratio of energy to rendezvous distance is maximum
S4=maximum $\dfrac{E^{\text{Rem}}}{d_j^{\text{Rem}}}$
Next Routing node=j(for S4)
End if
End if
End if
If (any set is empty)**then**
increment packet drop by one
End if
Repeat process till packet is dropped or delievered
End while
End if

Rendezvous Rotation Scheme

Rendezvous nodes are over utilized as they have to receive more no. of packets and send them to the rendezvous points which are at maximum distance R from the rendezvous node when sink arrives and stop at that location. To prolong the network lifetime rendezvous nodes must be rotated.

$$f = \max\left[W_1\left(\frac{E^{\text{Rem}}}{E_{\max}}\right) + W_2\left(\frac{N_D}{N_{\max}}\right) + W_3\left(\frac{N_P^B}{N_T}\right)\left(1 - \frac{d^{\text{Ren}}}{R}\right)\right]$$

Subject to

$$W_1 + W_2 + W_3 = 1$$

$$E^{\text{Rem}} \ge E_{th}$$

$$d^{\text{Ren}} \le R$$

$$B^{Space} \ge B_{th}$$

E^{Rem} is the remaining energy of each node. E_{th} is the threshold energy, N_D is the density or number of neighboring nodes. $N_{\max}$ is the maximum density observed around any node. N_P^B defines the number of not delivered packet by nearby rendezvous node. N_T is the maximum buffer capacity. d^{Ren} is the distance of any node from nearby present rendezvous node. W_1,W_2,W_3 are weights of energy, node density and closeness to existing rendezvous node respectively. B^{Space} and B^{th} are available buffer space and buffer threshold respectively.

To maintain uniform distribution, it is required that new rendezvous nodes are selected nearer to old one. In proposed algorithm at max only one best node is selected within the radius of each old rendezvous node as shown in constraints. It is also necessary that new rendezvous nodes have sufficient energy to carry out the given task. The node surrounded by more nodes have more possibility to reserve more packets as event is randomly generated hence these nodes should be given chance to be rendezvous node. Old rendezvous node have some undelivered packets to sink so when new rendezvous is selected old rendezvous node has to carry forward them to new one so for energy saving purpose it is necessary the new rendezvous node are close to old rendezvous node. The new rendezvous selected nodes replace the old rendezvous nodes after some specific round and whole process is repeated. The no. of rendezvous nodes at each round remains same as old rendezvous node, so load balancing is disturbed. Again genetic algorithm runs and rendezvous points location are found.

IV SIMULATION RESULTS

We have evaluated the performance of proposed multiple sink circular routing (MSCR) scheme with Stationery sink Scheme by extensive simulation carried out in MATLAB. Sensors deployed area is considered 1000*1000 m^2 in whole simulation.
Figure 4 shows the paths for multiple mobile sink and rendezvous point on each sink path. Green squares indicate rendezvous points. Sink stops at this point to collect packets from nearby rendezvous nodes.

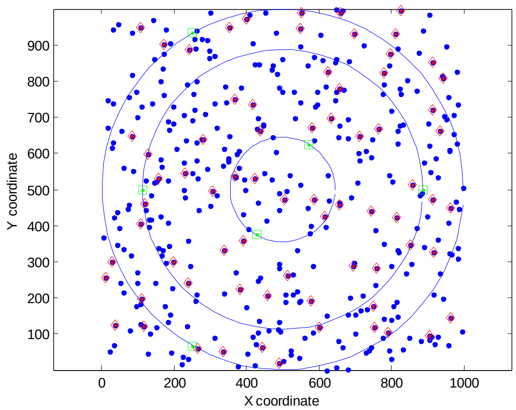

Figure 4 Paths for multiple mobile sink

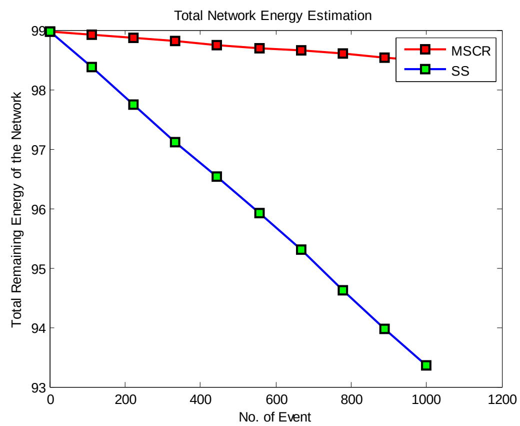

Figure 5: Analysis of energy consumption

Figure 5 shows analysis for energy consumption between MSCR and stationary sink scheme for center position of stationary sink for 400 nodes. Our proposed scheme saves more energy than stationary sink (center) Scheme where sink is placed at the center of field. In our proposed scheme sink collect the data by moving in the field where in stationary sink Scheme sink is stationery and not move from its location. In our proposed scheme the node has to forward the packet to nearby rendezvous node only so packet has to travel small distance compared to stationary sink.

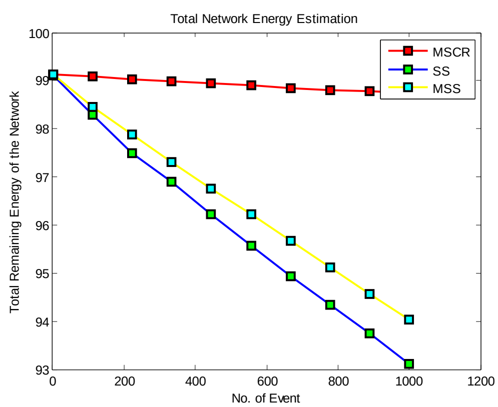

Figure 6: Comparison of energy consumption of MSCR,MSS,SS

Figure 6 simulation results carried out for energy consumption between MSCR, stationary sink and multiple stationary sink scheme for center position and corner position of stationary sink for 400 nodes. Our proposed scheme saves more energy than stationary sink and multiple stationary sink.

Fig 7 shows simulation results carried out for network lifetime calculation for various node densities. Results indicate that in our proposed MSCR number of dead nodes are less than stationary sink scheme for centre position of stationary sink at various node densities. In stationary sink case node has to forward the packet in direction of sink, so nodes around sink re over utilized and energy is depleted. In our proposed scheme rendezvous nodes collect the packet and are rotated after some rounds and strong capable rendezvous nodes are selected.

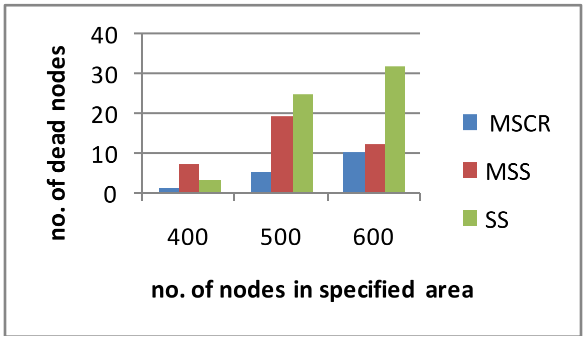

Figure 7: Comparative analysis of dead nodes

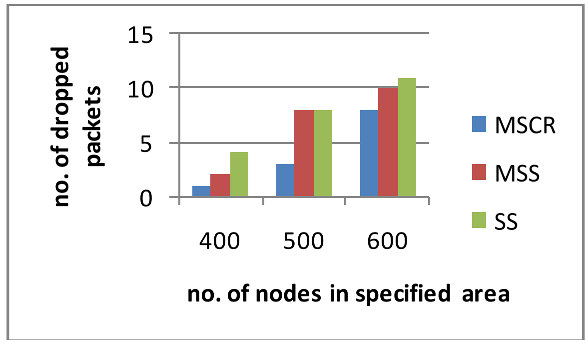

Figure 8: Comparative analysis of packet drops

Figure 8 shows simulation results for packet drops in MSCR and stationary sink. We have assumed that packet is dropped if packet occupied node does not found any suitable node surrounded by it. Results show that numbers of packet drops are significantly reduced in our proposed scheme as packet reach rendezvous node with less number of hops which decrease dropping probability of the packet.

V. CONCLUSION AND FUTURE WORK

All the simulation results carried for proposed scheme suggest that proposed scheme performs better than stationary sink scheme in terms of energy efficiency and packet drops. Number of dead nodes is also reduced hence leads to expansion of network lifetime and energy saving. Proposed scheme always select capable nodes hence all nodes are fairly utilized and better energy saving is achieved. In our work we have divided the network in form circles that form the paths for multiple mobile sink. One sink moves on each path. Rendezvous points are selected on this path. Mobile sink estimates hotspot and hence increase network lifetime. In this manner proposed scheme is more efficient in energy saving.

Multiple sink circular routing scheme is proposed for delay tolerant applications without considering the deadline of nodes. In delay sensitive applications packets must reach nodes before deadline and speed of each sink is considered similar. In real time application speed of each sink varies. Performance will be more enhanced if this two factors are incorporated with increased network lifetime.

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