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An Improved Hybrid Technique for Energy and Delay Routing in Mobile Ad-Hoc Networks

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Abstract

A mobile ad-hoc network (MANET) comprises wireless mobile nodes that dynamically establish a temporary network without needing a central administration or an infrastructure. The Quality of service (QoS) enables a mobile network to interconnect wired or wireless networks. An important research background identifying a path that satisfies the QoS requirements, such as their topology and applications, has become quite a challenge in mobile networks. The QoS routing feature can also function in a stand-alone multi-hop mobile network for real-time applications. A QoS-aware protocol aims to find a stable path between the source and destination nodes that satisfies the QoS requirements. The proposed method was a new energy and delay-aware routing protocol that combines cellular automata (CA) with the hybrid genetic algorithm (GA) and African Buffalo Optimization (ABO) to optimize the path selection in the ad-hoc on-demand distance vector (AODV) routing protocol. The main conclusions of this research include two QoS parameters that were used for routing: energy and delay. The routing algorithm based on CA was used to identify a set of routes that can satisfy the delay constraints and then select a reasonably good route through the hybrid algorithm. Results of the simulation showed that the proposed approach demonstrated a better performance than the AODV with CA and GA.

Keywords: mobile ad-hoc network, cellar automata, genetic algorithm, African Buffalo Optimization, ad-hoc on-demand distance vector, quality of service.

INTRODUCTION

A mobile ad-hoc network (MANET) exhibits a dynamic topology that does not contain any fixed infrastructure, with each node having host and router functionalities [1]. The most critical features of a MANET include autonomy and the absence of infrastructure, dynamic network topology, multi-hop routing, limited physical security, device heterogeneity, and variable capacity links with constrained bandwidth [2, 11]. The attributes of a MANET have various applications even with numerous constraints [15, 20]. These attributes include high ability in circumstances where a fixed infrastructure does not exist [19, 9]. The second feature is that a MANET does not have to operate on its own because it can be attached to the Internet and be incorporated in various devices, making its respective services available to the rest of the users. MANETs have been used in numerous applications in the past. Establishing the path from source to destination is crucial when using MANETs to deliver a data packet that satisfies the quality of service (QoS) standards, such as the end-to-end delay, throughput, and energy. Nevertheless, the algorithm designed in this study should be comparable with the QoS-based method in terms of the average end-to-end delay. However, the proposed algorithm is more effective in terms of node lifespan and packet delivery ratio. African Buffalo Optimization (ABO) [4] constitutes an effort to develop a convenient, reliable, efficient, effective, and easily implementable algorithm that will exhibit outstanding ability in exploring and exploiting the search space. The hybrid algorithm will be integrated with the ad-hoc on-demand distance vector (AODV) routing protocol to improve the QoS. Numerous artificial and heuristic QoS routing algorithms have been suggested for application in MANETs routing [1, 5].

Basically, routing is divided into several categories: single- and multi-path routing; source routing, and next step, hierarchical, and flat routing; centralized and distributed routing; data- and address-centric routing; QoS-based and best-effort routing; event-driven and queue-based routing; and energy-based routing. Many articles have discussed this issue and used several methods, which were often heuristic and intelligence tools.

Genetic algorithm (GA) is one of the most popular methods. A fuzzy GA is used for QoS routing [7]. The exact information protection of global network status is impossible for the nodes of a real dynamic network. Therefore, at first QoS parameters were fuzzed, and then became fuzzed to optimize the fitness function using the GA. Meanwhile, one of the related studies on multiple QoS routing algorithms based on GA was introduced [8]. Evolutionary optimization strategy, which is used in QoS multiple routing, is one of the other intelligent methods [17]. In the article, an evolutionary multi-purpose quick method was proposed as the Multi-Objective Evolutionary Algorithm (MOEAQ) to find the optimized path of the QoS. It was better than its basic version because of its convergence. In addition to high diversity, it could obtain more favorable results than the popular routing algorithm based on GA [12]. QoS routing could be performed by comparing several intelligent methods [3].

Swarm intelligence is a new and modern field inspired by the swarm behavior of creatures [12, 6]. The cellular model simulates the natural evolution from the perspective of the individual, which encodes a tentative (optimization, learning, search) problem solution. A cellular automaton (CA) has been shown capable of resolving various complex systems, such as MANET and issues in varied applications. A popular approach based on CA and employed in routing includes the Lee algorithm, which identifies the path that has the lowest aggregate weight on the grid [18]. The algorithm needs to establish the shortest path from the source cell to the destination cell when the weights of all the nodes (grid points) are configured as one. In the framework utilized, the authors considered the possibility of a relationship between the number of states and the longest path or the largest aggregate weight. Meanwhile, GA constitutes a search heuristic that mimics the natural process of evolution and is normally employed in generating solutions applicable in handling search and optimization problems [10, 13]. The composition of an ad-hoc network includes spatially distributed autonomous systems where intermediate nodes communicate with each other. Every mobile node can deal with route broadcasting even without requiring a consolidated controller. However, the main challenge is on lowering the power consumption of the various mobile nodes because each node has a limited battery power.

The GA-based routing algorithm has been observed to lead to the development of a heuristic methodology for MANETs. Nevertheless, the algorithm tends to speedily converge to a single solution through GA but causes network congestion. The work in [18] attempted to integrate genetic algorithm (GA) with cellular automata (CA) to improve efficiency. However, the main objective of this study is to solve the following disadvantages:

a. GA does not guarantee that the global maxima will be attained. However, in addition to brute force, GA does not guarantee the global maxima when dealing with non-trivial issues. However, the possibility of being fixed to the local maxima at initial phases is an issue that must be addressed, for instance, with a form of simulated galvanizing mutation rate decay.
b. GA consumer time before convergence is reached. A decently sized population and numerous generations are necessary to attain desirable results. With heavy simulations, a solution will often take days to obtain.

AN EFFICIENT ENERGY AND DELAY ROUTING PROTOCOL

Hybrid Algorithm Gaabo

The genetic Algorithm have been used to solve different problems, one of them is an energy problem that shown in Ahmadi scheme. But the GA still consume a high amount of time to get an optimum solution moreover, stuck in local optima. This research proposed a hybrid algorithm to solve the GA problems. This algorithm combines the advantages of both GA and ABO algorithms. The ABO is a response to create the population and discover the initial solution. The GA selects two solutions from an initial solution that comes from ABO. Then, it performs the crossover and mutation process till produce the best solution for GA algorithm. Next, ABO checks the state of the solution based on the fitness. Thereafter, it will make an update for the buffalos' position. Then check the stopping criteria. Subsequently, get an optimum solution. Overall steps for a hybrid algorithm are presented below.

Step 1: Initialization of Population is done randomly. Buffaloes are placed at nodes in a random manner.

Step 2: Determine Fitness of population by the following equation

$$m_k' = m_k + lp1(bg - w_k) + lp2(bp.k - w_k) \quad (1)$$

where

Lp1,lp2 → learning factors
Bgmax → herd's best fitness
Bpmax.k→ individual buffalo's best fitness
Wk mk→ exploration and exploitation movement of kth buffalo
K=1, 2…., N.

Step 3: Repeat

- Select parents from the population.
- Perform Crossover on parents, creating a new population.
- Perform Mutation on New population.
- Determine Fitness of the population.
- Update location of New child (bg_{max}, bp_{max}) by using the below equation:

$$w.k + 1 = \frac{(w.k + m.k)}{\pm 0.5} \quad (2)$$

- Check bgmax is getting updated, If Yes Check Stopping Criteria (Step 4) If No Initialize population (go back to step 1).
- Check Stopping Criteria, if met go to Step 4 else go to step 2.

Step 4: Output Best Solution.

All the proposed stages can show in figure 1.

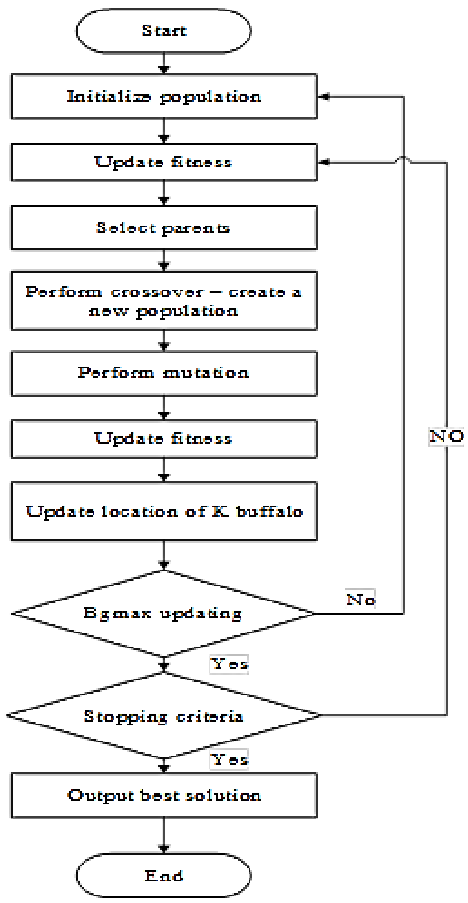

Figure 1: hybrid algorithm

Implementation of Discovering Routes by CA

The aspects of the executions are understood from the explanation of the mapping of CA using the MANET topology. A two-dimensional network plane in which several mobile nodes are spread randomly is considered in this study, to find out a path with delay as the QoS constraint. There exists no hierarchy among the nodes, and the network plane is found to be fully homogeneous (i.e. all nodes consist of the same characteristics).

Our approach involves the broadcasting of the RREQ message that constitutes the delay requirement of the connection request [maximum delay (Dmax)] by the source node to its communicating neighbors. All the nodes at the right, left, top, and down side are involved in this, as depicted in Figure 2.

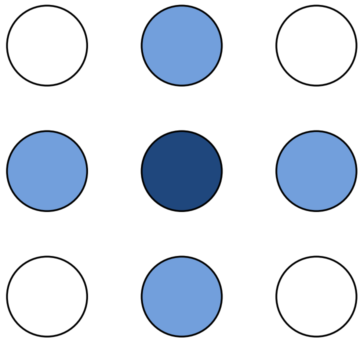

Figure 2: CA mechanism

The message re-broadcast by the intermediate nodes to their neighbors, which also establish a reverse path to the sender. Certain nodes, when given a delay constraint, turn into a wave, take in a wave node to their neighbors, re-broadcast the message, and establish a reverse path to the nodes from which they had obtained the message. This activity continues till the message is collected by the destination node or the delay faced by the packet outstrips the limit Dmax. The destination obtains many RREQ messages for the same sender when there are more paths from the sender to the destination. Consequently, reply to some of the RREQ messages is done by the destination through sending an RREP message through the reverse path that is established when the RREQ messages are passed on. The entire set of nodes observed along these routes amidst the source and the destination constitute the path nodes. Each and every communication between the source and the destination from this juncture happens through this path till the topology of the network gets modified... However, the Pseudo code for the MATLAB developed code can found bellow:

Algorithm for two-way dimensional of CA for the initial and shortest path.

- **i.** Input the radius of the CA K=1;
- **ii.** Put loop for the loop for discovering and checking loop for checking both side route from sn-dn and dn-sn
- **iii.** checking the neighbours of CN node ,which [r,c]= find(O == CA)
- **iv.** storing path created by nag node with concatenating original sn node
- **v.** concatenating dn to created path

Figure 3 shows the rule process of selecting a path by CA.

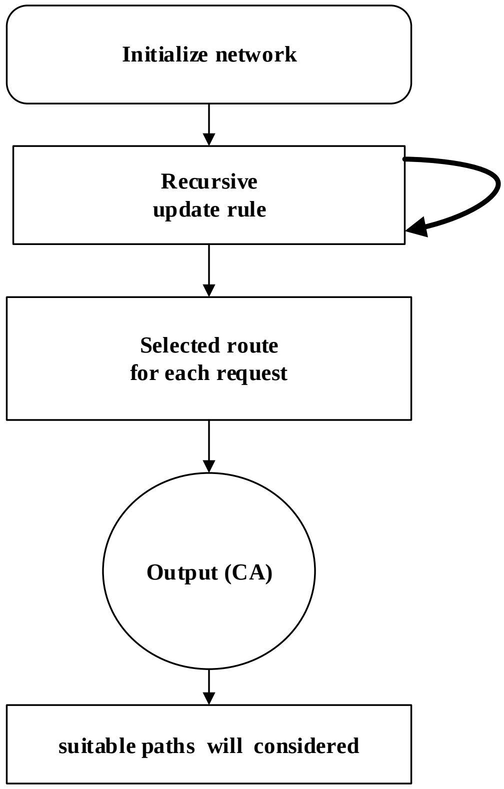

Figure 3: The Process rule for short path selection

System Model

In general, the reactive routing protocols create a path by using two types of messages; route request and route reply. The source node broadcast the RREQ to discover the possible path to the destination when the destination node receives the RREQ message it will send an RREP message to the source node. In protocols like AODV, the path is creating via sending an RREQ by source node till receiving an RREP from a specific destination. However, the AODV select the path based on the first RREP that comes from destination rather than the energy level of the nodes, this mechanism leads to exhaust node in the path and increase the probability of link failure, the link failure has negative effective on the QoS of the network such as; throughput, E2E delay, energy consumption, etc.

This paper, attempt to establish a robust path and get fulfill the QoS requirement as energy and delay. This research comprised two stages to achieve our objective, in the first stage we used CA to discover all possible paths based on minimum time, the second stage selects the path based on highest energy level for each node in the path by using hybrid algorithm GAABO. We proposed hybrid techniques that will enable the discovery of routes in MANETs which satisfy both the delay constraints and some simple energy constraints (every node on a path has a minimum energy level).

Aforementioned, the CA generate the paths from source to destination nodes based on the minimum delay, the RREQ message that sends by CA content a threshold term to ensure all paths achieve the requirement of delay. Subsequently, the hybrid algorithm checks the status of paths based on energy level. A hybrid GAABO with CA shown in figure 4.

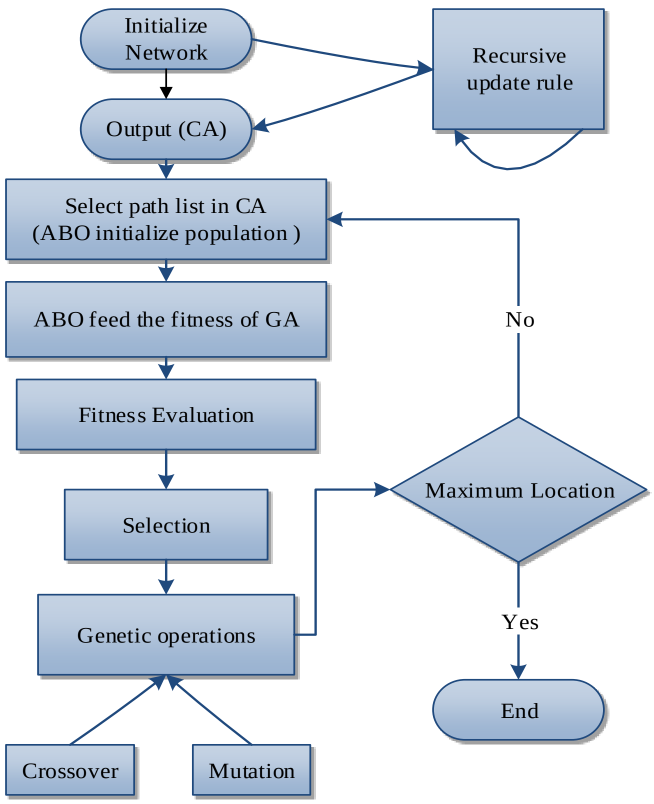

Figure 4: The process of CA with hybrid algorithm

The behavior of the ABO algorithm in nature is searching for the best pasture. The herd of buffalos' discovers the best place by sending different buffalo to a different place in the space. The buffalos' communicate between each other by sound. Each buffalo has two kinds of sound (maaa, waaa). The maaa sound means a place is a good place for the herd. On the other hand, the waaa sound means the place is not good (no pasture or danger) for the herd.
These characteristics of ABO are used in MANET. Figure (4.4) illustrate the steps of proposed approach. As mentioned before, the CA creates an initial population based on less delay. Then, the ABO use the population that generated by CA to select the path based on energy, each node in the network represent as buffalo in ABO, as mentioned earlier the buffalo (node) has two types of sounds(messages)these messages are uses to indicate the energy level of each node in the networks. All nodes forward the information of energy to the source node (herd). There are different paths are discover from source to destination nodes. The fitness function of ABO evaluates the quality of paths then sorts them. Moreover, get an optimum solution from all possible solutions, the GA selects two best solutions from a list of solution that generated by ABO as parents. Thereafter perform the operation of GA (crossover and mutation), then select the best solution (path). Through this mechanism get an optimum path with QoS requirements (less delay and highest energy level).

SIMULATION ENVIRONMENT

This section represents the parameters that use to implement the proposed approach and AODV. MATLAB toolbox was utilized to implement and evaluate the performance of routing protocols. To evaluate the behavior of protocols we changed the nodes speed as (5, 10, 15, 20 and 25), with node density 625 node, these node distributed in Random Way Point (RWP) within 3000m^2, packet size 512, CPR is controlled the traffic and pause time 5ms. The different performance metric utilized to evaluate the performance of the protocols:

a. **Packet loss ratio (PLR):** define the ratio of the difference between the number of data packets sent and received.
b. **Packet delivery ratio (PDR)**: the ratio of the data delivered to the destination node to the packets transmitted by the source.
c. **End-to-end (E2E) delay**: This metric represent the amount of time spent to transmit the data packet from source to destination.
d. **Throughput (TP)**: defined as the number of bytes that have been successfully received by the destination.
e. **Energy Consumption**: defined as the amount of energy consumed by all nodes in the network in a given simulation time.

RESULTS AND DISCUSSION

After the simulation was completed for the proposed method, performance analysis was conducted using the evaluation metrics, PDR, E2E delay, energy consumption, PLR, and TP. A simulation study was conducted by varying node speeds of 5, 10, 15, 20, and 25 m/s to show the effectiveness of energy cost on AODV routing protocol using CA with hybrid GA+ABO.

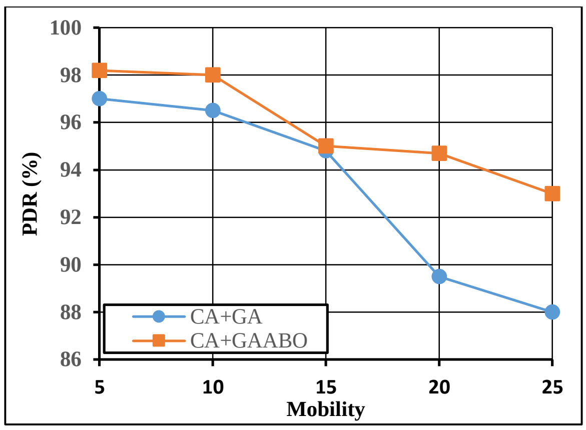

Figure 5: Packet Delivery Ratio

Figure 5 shows the packet delivery ratio for protocols, which have a different PDR. However, the proposed approach has a better result in PDR than CAGA protocol. Due to the CA with GAABO establish a stable path based on less delay and highest energy between source and destination nodes. This minimizes the probability of link failure as well as packets loss.

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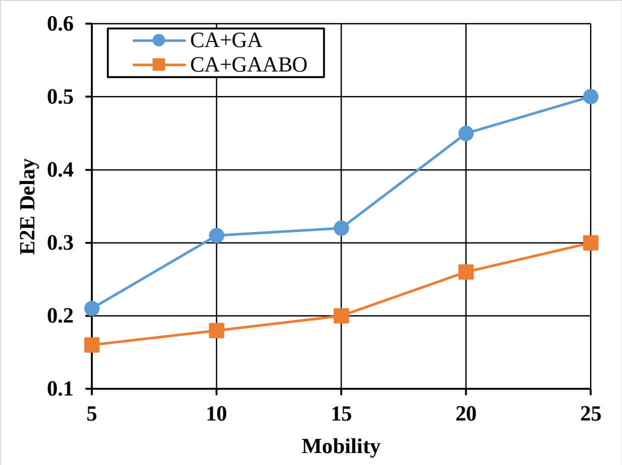

Figure 6: E2E delay

Figure 6 depicts the E2E delay for CAGA and CA with GAABO. That has a different E2E delay with the increase of the node mobility in the network. In the term of E2E delay, the proposed approach is better than CAGA protocol. Since the CA with GAABO searching for the path from source to destination nodes relay on the minimum delay between the nodes.

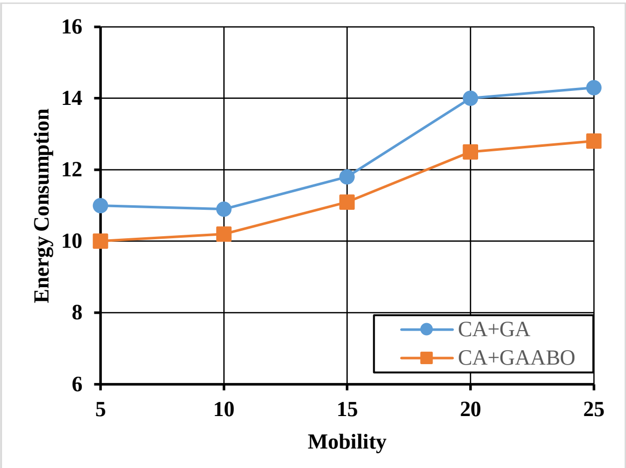

Figure 7: Energy Consumption

The variation of energy consumption for the CA with GAABO and CAGA are presented in figure 7. For all strategies, as the node mobility increases the energy consumption increases also. Results clearly show that proposed approach is better than another approach in term of energy consumption. Because once the protocol selects the best path, then, the same path will be used to transmit all packets. This path is highest energy level. Therefore, as the intermediate nodes will not perform route discovery and it need not have to waste its battery power.

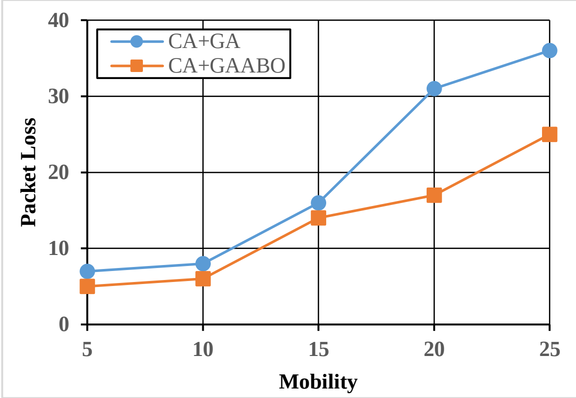

Figure 8: Packet loss

Figure 8 shows the variation of packet loss with mobility. When the mobility increases as (5, 10, 15, 20, 25) m/s, the packet loss increases also. The CA with GAABO has better performance than CAGA protocol in term of packet loss. Due to proposed protocol selects the route with less delay and highest energy, which saves time for the packets to be transmitted over the network.

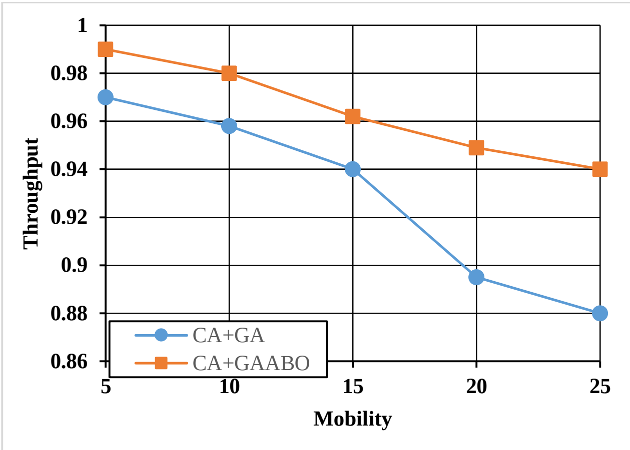

Figure 9: Throughput

The variation of average throughput for protocols is shown in figure 9. While the node mobility increased as (5, 10, 15, 20, 25) the throughput decrease in routing protocols. CA with GAABO protocol has better throughput than CAGA, as it selects the most active route to the destination. This route has less delay and more energy level than other routes; therefore the link is more stable which leads for fewer packets dropped. This, in turn, increases the throughput.

CONCLUSION

A wide range of fields, such as commercial and military applications, employ MANETs. Thus, establishing a path from source to target is essential to ensure that the data packet delivered meets the QoS requirements. However, this paper proposed a QoS-routing algorithm applicable in MANETs, which satisfies energy and delay constraints. In other words, the algorithm must support the QoS parameters of energy and delay. Using CA with GAABO techniques, this study sought to enhance the network lifetime as well as the E2E delay.

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