

Received August 8, 2019, accepted August 27, 2019, date of publication September 23, 2019, date of current version October 7, 2019.

Digital Object Identifier 10.1109/ACCESS.2019.2943013

Intelligent Data Delivery Approach for Smart Cities Using Road Side Units

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ABSTRACT Smart city progress from classical homogenous technologies with limited facility to heterogeneous interconnected network with immense capabilities. Furthermore, there is a good concern in expanding the scope of application in the smart city. The primary objective of the smart city is to achieve optimization and reinforce the Quality of Service (QoS) of applications by cleverer usage of urban resources. The QoS in the network is measured using several factors like end-end delay, energy consumption, packet loss and throughput. Several pitfalls are experienced in the existing routing innovation. In this proposal, a new technology-based routing structure is proposed. Road Side Units (RSU) will allow the planners to deploy the application without unfamiliar tools for data process and gathering. Data forwarding, acquisition and diffusion are simplified by RSU. K-Nearest Neighbor is used for finding the nearest neighbor nodes and it is optimized using Whale optimization Algorithm (WOA). The evaluation outcomes prove that the intended routing plot provides much spectacle than existing protocols for real time applications.

INDEX TERMS Smart city, routing, RSU, k-NN, WOA, QoS.

I. INTRODUCTION

Smart city is a groundwork of urban development and viable social-economic growth. Smart City permits people and things to be related at whenever, anything and everybody ideally the usage of any direction and any provider. Smart City upturns the life agility of citizens. Smart cities are a vital driver of IoT (Internet of Things) application development. The connection process in IoT consists of two processes namely sensing and routing. The facility of wireless, optical and sensor network presents the maturity of Information and Communication Technology (ICT). ICT enhance the prominence of Smart city by better use of resources. The aspect of ICT system is to associate data from heterogeneous resources (e.g. safety camera, street lights, parking spaces). Heterogeneity implies that there are different forms of sensor nodes such as surveillance camera, cars, buses, mobile phones, pedestrians wearing wearable computing devices and RSU. In urban sensing tremendous modification in mobile phones encourages the exertion of

cellular phones as beacon signals for transmission. Urban energy efficiency issues are handled through technology-based solutions. In lieu of touring all nodes in the network, some significant nodes are preferred for data agglomeration. Road Side Unit (RSU) is the access point along the roadside that provides data connectivity between nodes. Using RSU evades the necessity of data routing by other nodes culminating in the renovated lifetime of nodes. To improve the lifetime of the devices, the power ingestion rate of a single node in the network must be shared uniformly and the global transmission for every single association in the network must be lessened. The RSU also diminishes the packet loss due to the preferable data transmission. Optimal function of RSU maximizes the connectivity in the network. In recent times, a lot of contributions are made to extend RSU battery life, transmission coverage, safety and robustness. Several low-cost small size RSU is planted at the continuous location in the city. This RSU are connected to the base station with a wired or wireless connection. In ICT roadside infrastructure ought to be nicely modelled due to the fact as it acts as access providers and gateways. SPARK [1] suggested by Lu R et al provides space for car stationing. SPARK performance is

The associate editor coordinating the review of this manuscript and approving it for publication was Rongbo Zhu⁵.

improved by installing a large number of RSU. The spatial-temporal coordinates of the slotted are buffered in RSU. RSU coordinates all activities with the pre-recorded information by availing services like navigation, anti-theft detection and disseminating information. Jeon *et al.* [2] introduced a new approach to upgrading the smart road functionality. Cloud Services are accessible by the vehicles. Here RSU has high storehouse and reprocessing capability to store and transmit the information from the cloud server to carriages. Chou LD *et al* proposed a smart lightning strategy [3] to save the electric cost. Here RSU is used to control the traffic light signal. RSU monitor traffic light based on the estimation of the present traffic condition and speed of the vehicles. Sommer C *et al* designed [4] RSU to calculate the channel and utility values. This increases the pace of the message delivery rate. Information beacon systems utilize the advantages of RSU to disseminate information instantly. Hwang T *et al* suggested [5] safety application to warn the pedestrians of nearby threat by measuring the travel delay. It calculates rendezvous time of both pedestrians and speedy vehicles. In [6] the author gives better deployment strategy that optimizes the scope in connection and mitigates energy depletion of RSU. Several authors' works on RSU deployment to obtain multi-objective optimization. Many reformations are made to prolong battery life, transmission range and overcome security issues. When compared to other devices in the network, RSU has the high delivery capability by virtue of its high energy, large bandwidth and unrestrained storage. Devices connected with RSU forms an ad-hoc arrangement with restraints on energy, the rate of flow and memory facility. The conventional routing protocol is not suitable for cosmopolitan city network. Accordingly, a new mechanism is proposed in which RSU plays a major part in routing. The objective is accomplished by integrating diverse infrastructures and services into coherent units which are controlled by smart RSU. It sends information back and forth between transducer and the fixed point. In this paper, section 1 focus on RSU usability in diverse offerings in smart towns, including traffic manage, security and surrounding solutions. Section 2 focus on the research gap and routing challenges in the smart city. Section 3 overviews the existing routing methodologies for the smart city crisis. Section 4 gives an elaborate explanation of the conception in the proposed methodology. Section 5 presents a brief report of the proposed topology. Section 6 and 7 covers simulation model and result from discussion. Section 8 confers empirical study on smart toll payment. The future scope of the result and conclusion are outlined in the section 9 and 10.

A. LOAD BALANCING IN CLOUD COMPUTING

II. RESEARCH GAP AND CHALLENGES

In smart town, a substantial number of resources will coexist and engage among themselves to complete, to be part of and take part in countless benefits. Consequently, the upcoming demanding solution will arise

A. MULTIPLE SOURCES / DESTINATIONS

Smart city is composed of multiple sources and destination. Previously the existing routing approach finds the route between single source and destination. Due to the development in technology and demands several source and destination are inevitable. Information flooding and packet collision are to be acknowledged before designing a routing approach. All the possible routes are stacked as tables that can be used in the route discovery process. At varied times varied routes are fashioned. Network information is broadcasted such that all nodes aware of the feasible routes. Sheng X *et al* planned [7] a new system for maximum likelihood evaluation of node localization. The tracking algorithm is used to count the number of targets in a particular space.

B. ENERGY REQUIREMENT

Sensor nodes are mostly derived by battery power. Most of them are rechargeable. Many advancements in sensor battery forge sensor to reliably operate well for more years with less cost maintenance. Routing approach must minimize the power consumption, without comprising the accuracy or data processing capabilities. With feasible energy consumption all operations must be completed. Nodes with less energy level must be discharged from the network. Akan OB *et al* proposed [8] IoEHT (Internet of Energy Harvesting Things) solutions for energy and data management. The energy level and availability must be ensured offline mode; therefore, the network structure must be designed accordingly.

C. AVAILABILITY

In the smart city the demand to yield records must be fast, reliable and effective. Resources are plenty available but used incomplete. Time between data arriving and data value extraction should be minimum. This kind of millisecond processing means using a system and approaches that delivers timely and cost-efficiently. Routing approaches must use the available resources productively. The availability of the resources must be known to all nodes in the network. Proper scheduling mechanism must be empowered to regulate the working phase of the sensor nodes. Chaudhari S *et al* proposed a resource prediction routing mechanism [9] where nodes identify the available resources for stable route sustainment.

D. LOCATION-DEPENDENCE

In some situation, the location of the data sends and the identity of the person who sends the data are concealed. In other cases, the location awareness of all nodes is necessary. In Location Based Dependence the citizen is pointed to the nearby resources. To identify the location, mobile phone network or GPS is utilized. Data collection is primarily established on the account of the location of sensor nodes. Location-based protocol maintains the neighborhood position to handle the routing feasibly. Sharma S *et al*

proposed [10] Bat Algorithm (BA) for finding the path. The bat use echoes to estimate the distance calculation.

E. SECURITY

Smart city is unduly unsafe to spams due to their dynamically changing topology. The contents should be from trusted sources. Routing protocol should be capable of handling different types of attacks. Despite, no protocol is fully secured from attacks being encountered. As nodes are deployed in wide environment security prevails as an important concern. Moreover, the nodes are limited in storage advanced cryptographic approaches are not applicable, hence a lightweight validation mechanism is recommended. Yi *et al.* [11] proposed a tiered architecture to impose privilege levels to the sensor nodes. The proposed architecture promotes concerted trust relationship among nodes.

F. MOBILITY

A mobile sink changes its position throughout process time. While moving, the service interruption should be avoided. Reduce the handover delay and packet losses are common challenges faced. The nature of the movement, its speed, direction and rate of change can naturally affect the performance hence protocols have to be designed efficaciously. Transition Count (TC) is viable for mobility estimation. The metric calculates the number of times the node moves from one grid to next. The associated metrics like speed, angular displacement and randomness value changes accordingly to the characteristics of the protocol. Ding *et al.* [12] proposed a novel approach that records the mobility information.

G. SCALABILITY

Limited storage, bandwidth and computational capabilities should not influence the Quality of Services (QoS). Owing to the huge number of nodes and high node density issues arises in designing routing protocol of highly scalable. Nodes must be configured into an ideal state or active state according to the event incidence. An agreeable routing procedure must be amendable and versatile to the alterations in the network configuration. Routing procedure that adopts hierarchical fashion sustains more energy. YucelS *et al* proposed [13] a restoring cluster strategy to recover the Cluster Head data and cluster member conjunction with CH.

H. FAULT-TOLERANCE

Nodes are susceptible to failures due to energy depletion, hardware failure and communication link error. Caching the state of the network knowledge can enhance the robustness of the nodes. Fault tolerant routing is a critical task for operating in a dynamic environment. Diverse levels of redundancy are essential to shield against various threats. Re-clustering and Cluster Head (CH) are mechanisms are utilized to preserve the properties of the cluster. Ensure the resilience of ICT services to defend against system failure. Lin JW *et al* proposed [14] a novel strategy by employing virtual CH to

accumulate the network information. Whereby virtual CH's are composed from the available free CH.

I. CONTEXT-AWARENESS

For efficient routing, it is necessary to gather the context of the device environment and scrutinize it for promoting knowledge. This knowledge is utilized for making the routing decision. The routing must be able to adapt its behavior accordingly to the learned knowledge. Sensor nodes sense huge amount of data where predominant data are not required for processing. Some filtering techniques are empowered to pre-process the non-essential data. You J *et al* proposed [15] a context-aware routing protocol called HobyCan. HobyCan uses context information of the sensor network for the development of detour paths.

J. HETEROGENEITY

Smart city lends in combining various technologies together. Heterogeneity reflects the presence of different devices with different efficacy. Routing approach should acquaint itself assuring technology that promotes the effective and seamless interconnectivity of extensive amount devices in an abstractedly way. Undesirable characteristics are exhibited if the nodes do not possess the same configurations. The CH selection for heterogeneous nodes varies from the traditional CH election. Kumar *et al.* [16] proposed a new mechanism to select the CH. The CH is elected based on the weightage values.

K. DATA REDUNDANCY

Smart city forwards a huge volume of data to the terminal for processing. In this way, regular exchange of the data leads to energy dissipation. Proper elimination of data repetition elevates the attainment of the routing protocol. Transmitting unnecessary data results in energy consumption, time delay and packet drops. Wang L *et al.* suggested [17] a new tier architecture to discard inaccurate data from Radio Frequency Identification (RFID) and to minimize the overall energy consumption.

L. CONGESTION CONTROL

The complex phenomena ensue when the capacity of the topology is greater than the capacity of the network. Packet loss and delay are the issues regarding congestion which results in performance decay. It is crucial that the routing protocol should try to surmount congestion. By expanding the network utilization, the effects of congestion control can be reduced. Chen L *et al* suggested [18] a resource allocation scheme for proper congestion avoidance and rescheduling. Maximizing the queue length lessen the traffic.

III. LITERATURE SURVEY

Behera *et al.* [19] has presented a new election scheme that nominates the Cluster Head (CH) based on the energy level among nodes. This scheme nearly reduces the obligation in the topology by reducing energy exhaustion.

Keshwani and Bhaskar [20] proposed flower pollination optimization for better deployment of sensor nodes in the area. Considering proper communication, nodes must be familiar with the location of neighbor nodes in the Region of Interest (RoI). But this method is suitable only for static node environment and not for the dynamic environment. Ahamad *et al.* [21] the fitness function to estimate the CH is optimized using Artificial Bee Colony (ABC) optimization. The preeminent aim of this method is to maximize the network lifetime by providing irresistible multi-path data diffusion to provide authentic communication even if the node stumbles. Elappila *et al.* [22] proposed enhancement in the communication protocol that improves the survivability for IoT applications in health monitoring. This strategy is applicable in the network with heavy traffic where more than one source sends data to the sink at the same instance. Jiang *et al.* [23] proposed Energy Efficient Minimum Criticality Routing Algorithm (EEMCRA) and Energy-Efficient Multi-constraint Re-Routing (E2MR2) to avail link load for absolute power and attain re-routing policy to advance QoS. EEMCRA discover the lowest energy dissipation among the possible paths. Reference [24] designed a distributed Novel Energy Efficient Clustering (NEEC) algorithm, the radius of each node in the network is established in a centralized manner and the node membership is decided in a distributed way as a deduction this compensates the energy depletion in the city and increases the number of repair packets to BS. Sensor nodes nearer to the target suffer from traffic responsibility at the time of communication henceforth using mobile sink greatly reduces the energy consumption. Wang *et al.* [25] proposed clustering and PSO (Particle Swarm Optimization) abilities are employed mutually to develop the entire implementation in conditions of average energy consumption and network lifetime. Here sensor network is subdivided into groups based on the geological location. In particular super-cluster, series of clusters with optimized PSO is established which is relied on the residual energy and distance vector of CH. At the end of chain formation, final cluster transmit fused data to the base station. Jesudurai and kumar [26] suggested Improved Energy Efficient Cluster Head Selection (IEECHS) that separates the nodes in the network into different partitions, two CH achieve data transmission in a planned. First CH is used to send information from members in the cluster and second CH is used to aggregate information from sink and communicates it to first CH and other members in the cluster. This method prolongs the energy status in IoT applications. The major concern of this method is to minimize energy utilization and fault tolerance. In real time scenario, traffic management application [27] processes a huge amount of data using Hadoop framework. ACO (Ant Colony Based Optimization) based routing substantially reduces the processing time. Here the network characteristics are plotted against the big data attributes. Due to the sudden shift of the mobile nodes, there is a strict obstruction in connectedness. Accordingly, Saleem MA *et al.* suggested [28] a modern solution for solving connectivity problem by positioning

mediators. The mediators are promoted for data congregation and establishing the best path for transmitting data packets. These mediators diminish the delay. Er Ni *et al.* proposed [29] Data Collection for Low Energy Devices (DC4LED) that minimizes the data delivery rate by employing Internet Point of Presence (PoP) in the city. It reaches high connectivity even in the low density of the network. It is important specifying other metaheuristic methods are applied in routing like Ant Colony optimization (ACO), Particle Swarm Optimization (PSO), Simulated Annealing (SA), Bat Algorithm (BA) etc. The detailed explanation of various methods and its versatility are explained by Hussain k *et al* in [30]. The methodologies are compared in terms like Mean Error (ME) and Standard Deviation (SD). Sensor nodes are associated with the IoT devices that are positioned in the Smart City. Here sensor node forwards the data based on the two activity models namely normal mode and IoT mode. The two modes possess a variation of energy levels, based on the circumstances the selection of nodes with least energy level is favoured. Hanif S *et al* proposed [31] a new method of exploiting IoT devices to stabilize the load in the network. Ahmed and Rani [32] proposed optimized AODV known as a hybrid approach. Bacterial Foraging Optimization (BFO) is used to select a substitute direction in WSN. BFO forms optimum clusters by reducing energy utilization and thereby to improve the sum of the alive nodes that enhance the resilience and endurance in the network. This hybrid process has exhibited advancement through the delay, energy, miss ratio of packet transmission and delivery rate.

IV. PRELIMINARIES

A. CONNECTED GRAPH

A graph $G = (V, E)$ where V is set of vertices (nodes) and E is a set of edges connecting the pair of edges. Graph G was connected if there exists at least one directed path between every pair of vertices. Let us consider all resource instances reclined on road. G is said to be associated if there prevails a path between every pair of vertices. Each edge has corresponded with non-negative weightage denoting the cost of the travelling period. A tree is a connected graph without cycles. The basic network forms a minimal spanning tree (minimal cost path from any vertex to any other vertex) where it connects all nodes. A communication network can be designed by a connected graph with vertices representing nodes and edges representing links.

Theorem 1: Let G be a weighted connected graph in which the weights of the edges are all non-negative numbers. Let Tr be a subgraph of G . Then T is a minimal spanning tree.

Proof of Correctness: Consider G be weighted connected graph, Tr is an acyclic subgraph of G with $n-1$ edges. If Tr has x vertexes and y connected components, then it has $x-y$ edges.

That is $n-1 = x - y$, since $x \leq n$ and $k \geq 1$, it happens that $n = x$ and $y = 1$, since $n - x = 1 - k$. Thus, Tr is connected and a

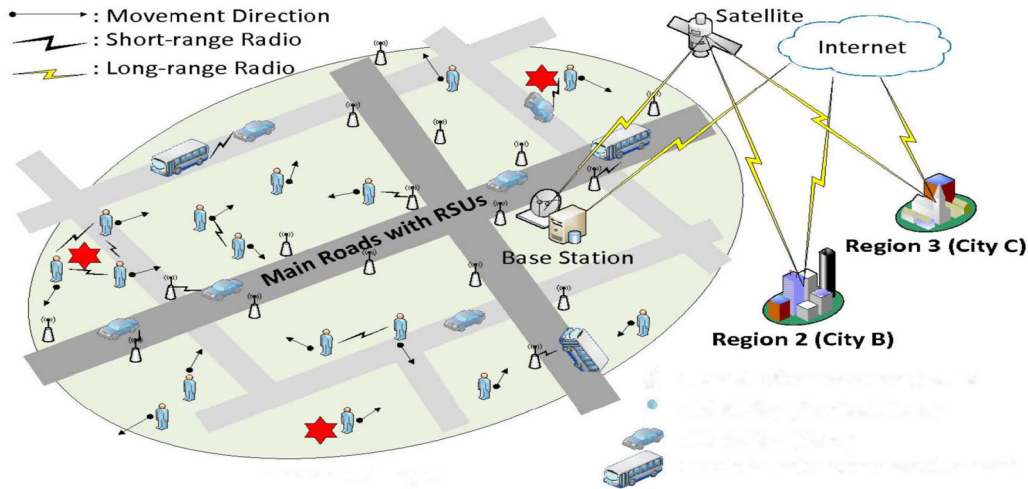


FIGURE 1. RSU and another nodes position in smart city.

spanning sub graph. Therefore, Tr is certainly a spanning tree of G .

Assume Sp is spanning tree of G with less weight than Tr . That is $W(Sp) < W(Tr)$.

Let e_1, e_2, \dots, e_{n-1} be the edges of T , first edges e_k does not lie in Sp . Therefore, Sp is different from Tr .

Then the sub graph H of G obtained by adding the edge e_k to s has n edges and so it is no longer a tree. Thus, the dependent H must contain a cycle C , C must contain the edge e_k , C would be in acyclic Sp moreover C must contain an edge of S that is not in Tr . Then the dependent $H-e$ is still connected, and it has $n-1$ edges, is also reaching tree.

The algorithm follows that, $w(e_k) \leq w(e)$, since $H-e$ has been formed by replacing e with e_k and $w(e_k) \leq w(e)$ that $w(H-e) \leq w(Sp)$. Repeat the same, finally we reach $w(Tr) \leq w(Sp)$. Since $w(Tr)$ is minimal after all. Therefore, Tr is minimal spanning tree.

Fig.2 shows the connectivity of the structure in smart city crisis. The proposed is said to be resolutely associated, since there was at least one directed path between every duo of vertices (RSU).

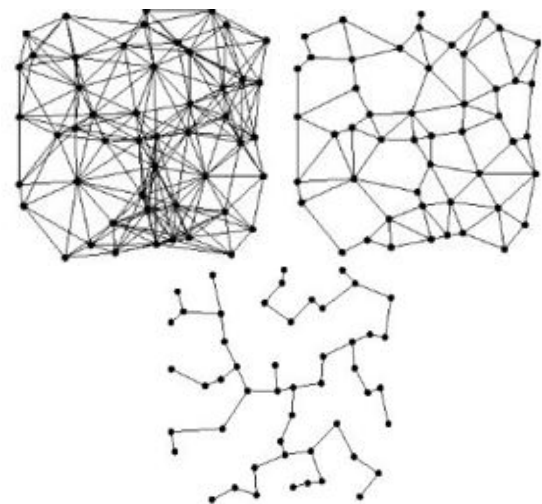


FIGURE 2. Representation of connectivity among nodes.

B. TRAVELLING SALESMAN PROBLEM (TSP)

The objective of this method is to find the shortest route between the set of points and locations that must be visited. In TSP the points are cities the salesman might visit. The objective of the salesman is to minimize the travel expense and distance travelled.

$TSP = \{(G, f, t) \text{ where } G = (V, E) \text{ a complete graph}$
 $f \text{ is a function } V \times V \rightarrow Z,$
 $t \in Z,$

$G \text{ is a graph that contains a tour with the cost that does not exceed } t\}$

The number of possible combinations increases exponentially. If the size of the city (the count of nodes) increases, then the complexity of the TSP also increases. If there are

N nodes, then the possible combination is $N!$ For example, consider there are 15 nodes then the possible combinations are $1.307674368 \text{ E}+12$. Now imagine a single node forwards packets by accomplishing 35 RSU a day that provides $1.033314796 * 10^{35}$. To lighten the load, several heuristics methods are practiced. Miao Y et al proposed a new strategy [33] based on Glowworm Swarm Optimization (GSO) to find the best k - sub tour paths for a mobile node.

Glowworm chooses the best neighbor based on the volume of the luciferin. In order to optimize the access points towards the global transmission range, GSO is considered to be the fittest. Sahana SK proposed [34] Ant Colony System (ACS) to enhance the pace of updating the routing tables. Routing table must be precise during the route discovery process. Ants use pheromones to study the path and direct it to other nodes. Geem ZW et al proposed [35] a Harmony Search (HS) based strategy to solve TSP efficiently. HS improves the

cost-effectiveness of load dispatch process by recollecting the earlier visited paths.

Fig shows the RSU's connectivity based on the underlying TSP formulation. The basic idea behind this structure is to facilitate the connection between each node in the network. All the RSU's are connected primarily to support the coverage range.

C. RSU COMMUNICATION – FLOODING AND GOSSIPING

There are two approaches of communication in the sensor topology one is direct communication, and another is indirect communication. In direct communication, the nodes directly connect with the base station. At worst complexity case a node may lie afield from the fixed point and transmitting data to the base station consumes a large amount of energy. In indirect communication, the data is transferred to the base station via intermediate nodes. This approach saves the energy of the source node, but it results in energy depletion of other nodes participating in the network. To conserve a large amount of energy in the network, immense powerful RSUs are deployed. This remarkably reduces the path length in transmission. RSU provides safety, mobility and environmental benefits in a smart city. RSU is necessary for data gathering and dissemination. The prolongation of the RSU transmission area by means of straightforward transmission of data for civic paragon is given in [36]. A low-level operation of RSU in the network is the delivery of a message from the source node to sink. A higher level of communication includes flooding and gossiping. Communication takes place in the hierarchy or single hop fashion. The accordance of the network may be continual or timely dependent upon the operations. Messages are broadcasted to the nearby nodes only.

1) FLOODING

$G = (V, E)$ be a graph and let $v \in G$ be a node in G , let v known a piece of information $V(I)$ which is unknown to further nodes in the network $V \setminus \{v\}$. Flooding provides a mechanism in which all nodes in G learn piece of information $V(I)$. In flooding, node sends packet to all its neighbors. It does not require maintenance of topology. Flooding is based on the construction of edge-disjoint trees. It consumes a larger bandwidth.

2) GOSSIPING

It is similar to flooding, where node sends a packet to randomly selected neighbor and the neighbor in turn, sends the packet to other randomly chosen neighbors. The motive of gossiping is that each node has a unique piece of information that is shared with interested neighbors. Gossiping reduces the counts of data packets in the field but delay reaching the destination is large.

D. K- NEAREST NEIGHBOR ALGORITHM

The Nearest Neighbor is a greedy algorithm used to solve TSP. NN is used to determine the points nearest to the current point. The goal of NN is to make a local optimum choice at each stage to find the globally optimal solution, i.e. the node

nearest will be served next. It is simple to implement and executes instantly. The NN algorithm proceeds with Euclidian distance (equation 1) to find the distance between two nodes. In the below equation d gives the distance measure between any two nodes a and b in the network.

$$d(a, b) = \sqrt{\sum_{i=1}^n (b_i - a_i)^2} \quad (1)$$

K-NN algorithm

Step 1: Select starting vertex V_1 of G .

Step 2: Select an edge $e = V_1 V_2$ of G such that $V_2 \neq V_1$ and e_1 has smallest weight among the edges of G incident with V_1 .

Step 3: If edge e_1, e_2, \dots, e_i have been selected including termini V_1, V_2, \dots, V_{i+1} select an edge $e_{i+1} = V_j V_k$ with $V_j \in (V_1, V_2, \dots, V_{i+1})$ and that $V_k \in (V_1, V_2, \dots, V_{i+1})$ such that e_{i+1} has smallest weight among these edges of G with strictly one end in $\{V_1, V_2, \dots, V_{i+1}\}$

Step 4: Terminate when $n-1$ edges have been selected, otherwise repeat Step 3.

E. WHALE OPTIMIZATION ALGORITHM (WOA)

WOA is a novel nature-inspired metaheuristic optimization mimics the social foraging behavior of Whales. Whales are warm-blooded, air-breathing mammals reside in the ocean. It belongs to the group of marine animals known as cetaceans. Humpback whale is one kind of cetacean. The whale is named after peculiar hump in front of small dorsal fin. Spindle cells in whales are responsible for judgement, learning and communication. Humpback travel alone or in a small group called pods. Humpback propels themselves above water and splashes back down. Slapping water is responsible for communication. They dine on small fish, Kerl and plankton. To eat prey, they take large gulps of water. They are known for haunting songs (cries, moans and howls) to attract potential peers. WOA [37] is a novel meta-heuristic algorithm suggested by Mirjalil et al., in 2016. The basic approach in WOA includes encircling prey, exploitation phase and exploration phase. For hunting prey, the bubble-net strategy is used. While encircling prey whales naturally form bubbles along spiral-shaped path. These bubbles cover around the prey and whales move towards prey in an upward direction. At the end of this action, it has more prone to achieve its goal and catch prey. This strategy is practiced in node location problem in the smart city.

1) ENCIRCLING PREY

The targeted prey is considered as the current best solution. Other individuals try to update their position towards optimal solution. The mathematical equation of encircling prey behavior is given below in equations 2- 5.

$$\vec{D} = \left| \vec{C} \cdot \vec{X}^*(t) - \vec{X}(t) \right| \quad (2)$$

$$\vec{X}(t+1) = \left| \vec{X}^*(t) - \vec{A} \cdot \vec{D} \right| \quad (3)$$

$$\vec{A} = 2 \cdot \vec{a} \cdot \vec{r} \quad (4)$$

$$\vec{C} = 2 \cdot \vec{r} \quad (5)$$

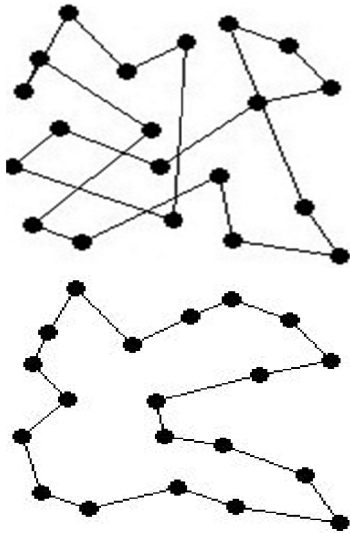


FIGURE 3. Road Side units connectivity based on TSP.

where t signifies present iteration. C and A are coefficient vectors. X^* indicates best solution vector. D is the distance amongst whale and position of preys. ‘ r ’ is a random vector in $[0,1]$ and ‘ a ’ is linearly decreasing vector from 2 to 0.

2) EXPLORATION PHASE

The bubble-net behavior of humpback whales is mathematically expressed as

Shrinking Encircling Mechanism:

The optimal solution is based on the historical position. Here, A has random value $[-a, a]$ and value of is decreased from 2 to 0 over the course of iteration as shown in Fig.3.

Spiral Position Update Mechanism:

The range amongst whale and prey is measured. The movement of whale along spiral shape is mathematically shown as in (6)

$\vec{X}(t+1) = \vec{D}e^{bt} \cos(2\pi t) + \vec{X}^*(t)$ Where \vec{D} the distance between whale and optimal solution, b is a constant for delimiting the form of the spiral curve and t is a random number $[-1, 1]$. The selection of shrinking encircling mechanism or spiral updates position is based on the probability (p) is a random number.

$$\vec{X}(t+1) = \begin{cases} \vec{X}^*(t) - \vec{A} \cdot \vec{D}p < 0.5 \\ \vec{D}e^{bt} \cos(2\pi t) + \vec{X}^*(t) p \geq 0.5 \end{cases} \quad (6)$$

3) EXPLOITATION PHASE

The vector A is appropriate for prey search. The search can be randomized by choosing value greater than 1 or less than -1. Here we select RSU randomly instead of best nearest RSU. The mathematical model is given as in equations 7 and 8

$$\vec{D} = \left| \vec{C} \vec{X}_{rand} - \vec{X} \right| \quad (7)$$

$$\vec{X}(t+1) = \vec{X}_{rand} - \vec{A} \cdot \vec{D} \quad \text{Where } \vec{X}_{rand} \text{ is a position vector.} \quad (8)$$

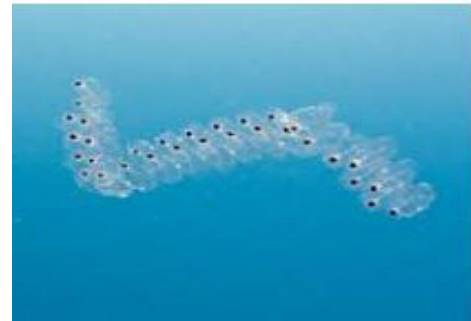


FIGURE 4. Spiral shaped movement.

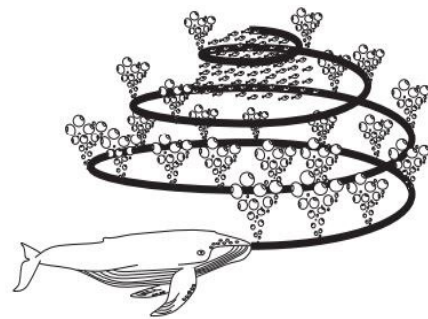


FIGURE 5. Bubble net feeding method.

V. PROPOSED ALGORITHM

In order to obtain practical simulation like heterogeneous architecture, considerable mobile nodes are introduced. The mobility behavior of nodes in the intended work is patterned by the random way point model as a result in which random positions to which node move are induced. The best k -nearest neighbors for sink node is elected by virtue of WOA. The maximum number of iterations is fixed. In each iteration, the fitness value of whale is computed. The optimized routing there exists at least one pathway for a node to interact with any other node. The optimal tour is desired under on the lowest hop energy of the path. The primary regard to use WOA is to conserve energy and suggested method is profitable for smart city applications. RSU is employed to hasten the speed of message delivery and it stores all the available paths and choose path with lowest energy consumption. The enviable purpose of proposed architecture in smart city network:

- Performs fine in heterogeneous architecture.

- Upgrade the use of RSU’s to enhance the performance in energy consumption and delay.

- Feasible implementation in practicable application.

A number of parameters are determined to estimate the performance of the aimed framework.

1. Delivery capability – Nodes deliver information depending on the hardware capability. Since here nodes are interconnected with RSU the overall delivery capability will be high.

2. Number of copies – Each node sends data by virtue of RSU path. Consequently, this reduces the duplicate copies of repeating data. Formerly each neighbor node in the network has to buffer the packet. By this approach storage utilization, network bandwidth, time and energy are reduced.

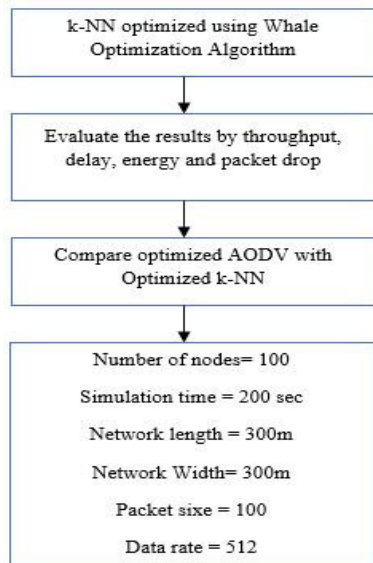


FIGURE 6. Simulation model.

3.Connectivity – A network is said to be connected if there exists a single-hop or multi-hop transmission pathway among any two nodes in the network. The connectivity is determined by the RSU deployment location and communication range.

4. Network Criticality–It is a robustness technique to capture the effect of environmental changes such as topological changes in the network. Large network criticality denotes unstable network.

5. Throughput–This is measured based on successful reception of data packets by the receiver. It is the ratio of the total number of data packets that reaches the receiver from transmitter to the moment it takes for the target to receive final packet. It is measured in pps (packets per second).

6. Energy consumption – It is valuable to prefer route over nodes with great residual energy with a view to sustain the lifespan and mitigate nodes with insufficient resources. The value of residual energy, transmission energy and reception energy are taken into account.

7. End to End delay –It is the delay accomplished by the effectively delivered packets in arriving their destination. This stands how efficient concealed routing protocol since it relies on the optimality of path chosen.

8. Miss ratio of data transmission-It is the difference between total numbers of packet sent and packet counts that delivered successfully. The lesser the value of packet drop means the better performance of the convention.

This method reforms the performance in terms of throughput, energy, packet drop and delay. It maximizes the purpose of RSU.

VI. SIMULATION MODEL

Node deployment is made in 300*300 extent. The topology for the placement is configured first whereby there are 15 RSU’s are fixed, nodes are fixed, and mobile nodes are generated random pattern. The maximum distance between

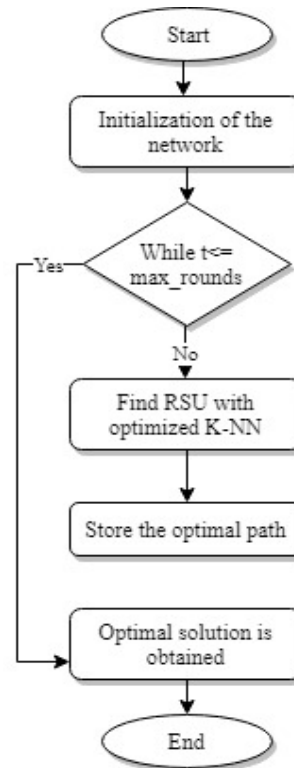


FIGURE 7. Proposed optimized K-NN method.

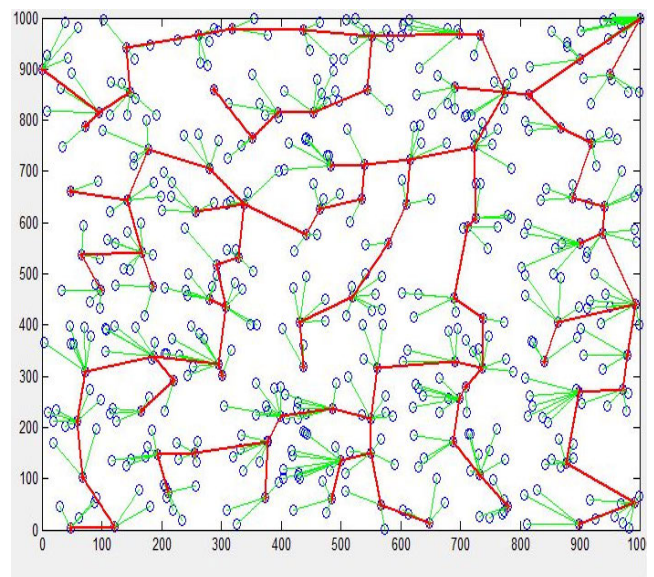


FIGURE 8. Proposed methodology.

any two RSU is 40 units. In extension, an innovative method is designed for optimization of k-NN using Whale Optimization Algorithm (WOA) to maximize the network lifetime. It is then compared to the optimized AODV in terms like throughput, packets drop, energy utilization and delay. In Fig.6 topology simulation is shown for 100 rounds. Fig.7 depicts the proposed optimized K-NN method. Fig.8 outlines the proposed methodology. Here red boundary indicates the

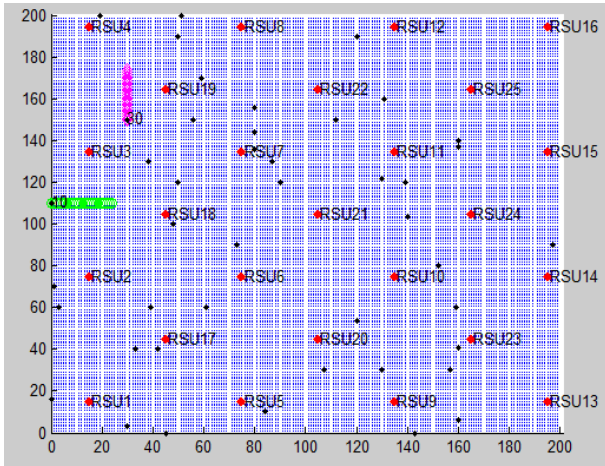


FIGURE 9. Movement of mobile nodes.

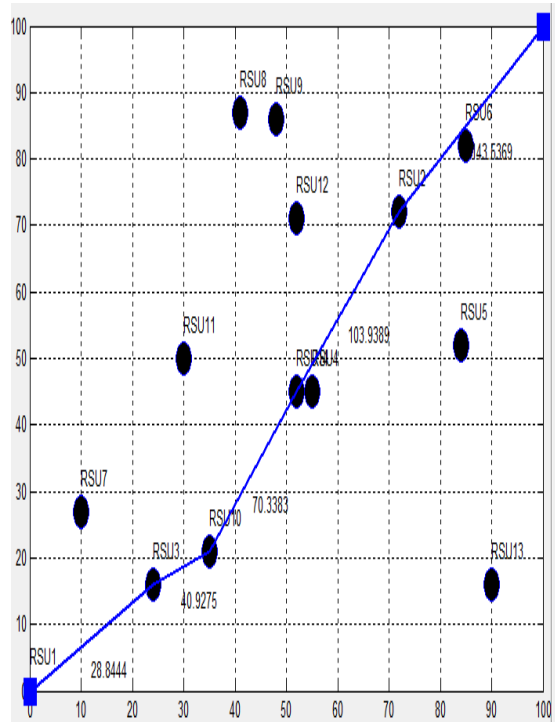


FIGURE 11. Path Back traversal.

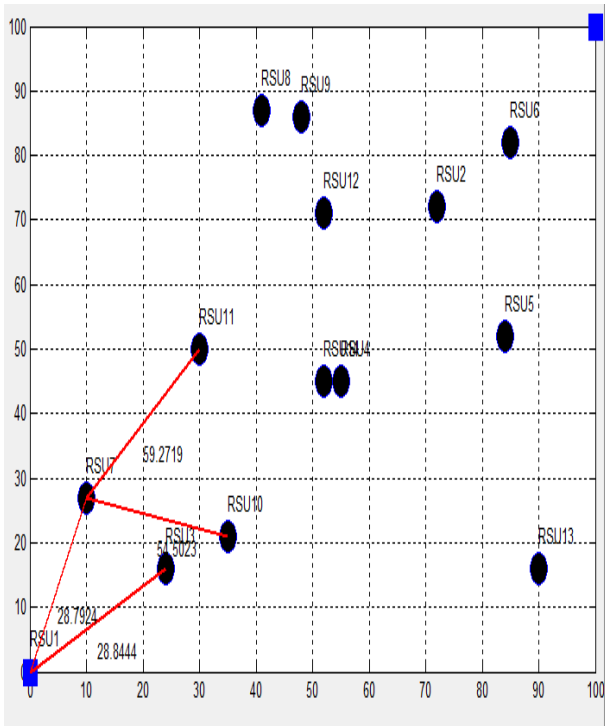


FIGURE 10. RSU path formation.

transmission lines between any two RSU and green boundary indicates the connection of RSU with other nodes.

Fig. 9 shows the movement of mobile node towards RSU that is optimized by the Whale Optimization Algorithm. Fig. 10 and Fig 11 shows path formation in RSU by means of K-NN. The nearest RSU is selected based on the Euclidian distance. All paths are buffered, and optimal path is stored based on distance and energy consumption.

VII. RESULTS AND DISCUSSION

Conclusions derived from the simulation conducted in MATLAB are shown from Figs.8-14. Delay is not bearable in smart city applications and the proposed method has shown advancement in this parameter. The proposed cut downs

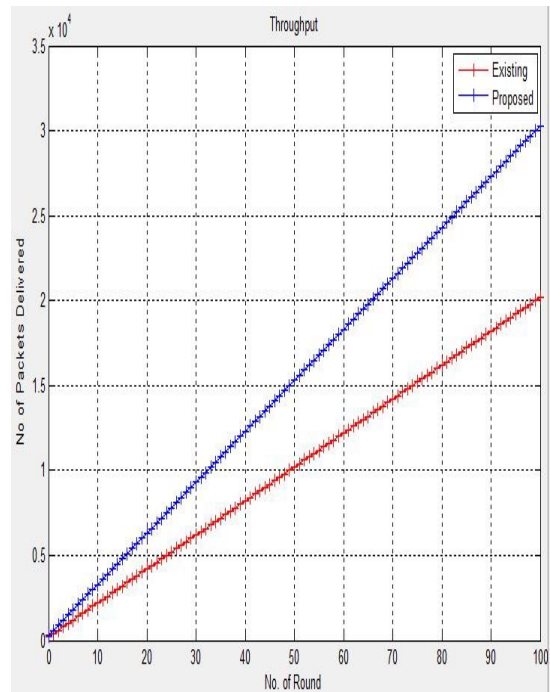


FIGURE 12. Comparison of throughput.

the delay from 24% to 19% compared to the existing protocol. Some packets are discharged when the source transmits the packet to the destination and this parameter should be reduced. The packet drops are less (17 %) in comparison to the existing (24%). The primary objective is to minimize the energy utilization and proposed method has conserved energy in an efficient manner. A node other than RSU saves nearly

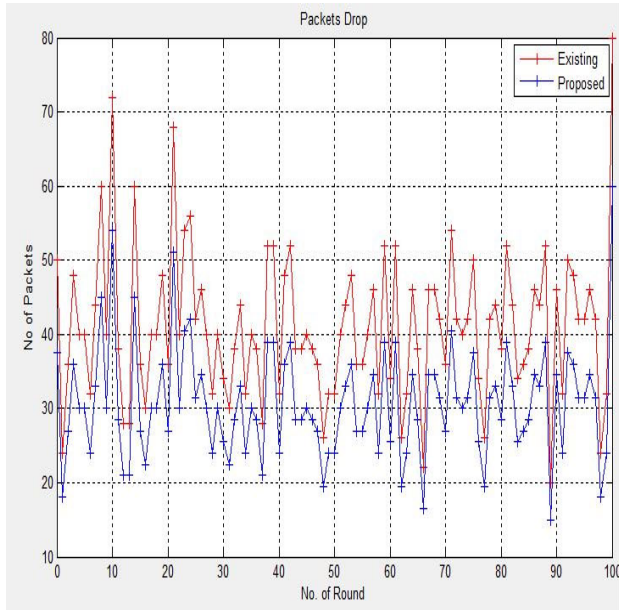


FIGURE 13. Comparison of packet drops.

TABLE 1. Comparison between proposed and existing approaches.

PARAMETERS	EXISTING	PROPOSED
Energy Utilization	89.82	67.37
Delay	24.83	19.86
Throughput	89.00	93.50
Packet drop	41.03	17.77

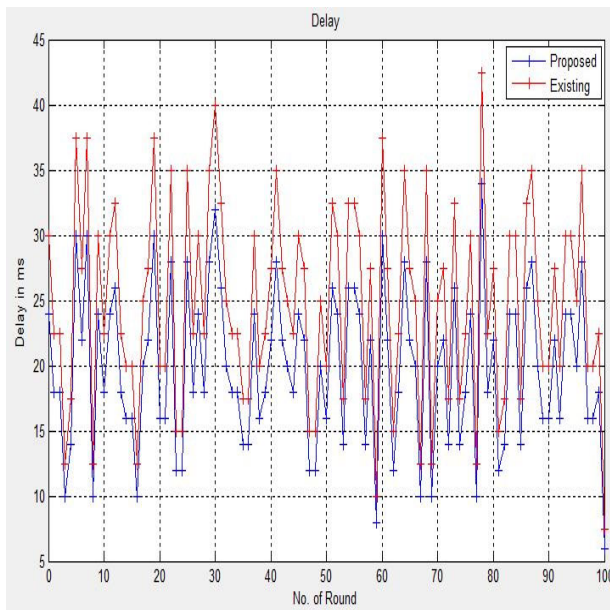


FIGURE 14. Comparison of delay.

48% of energy by this approach. Despite ensuing 100 rounds of data transmission, a vast amount of energy is sustained. The packet delivery ratio (throughput) is decisive to analogize

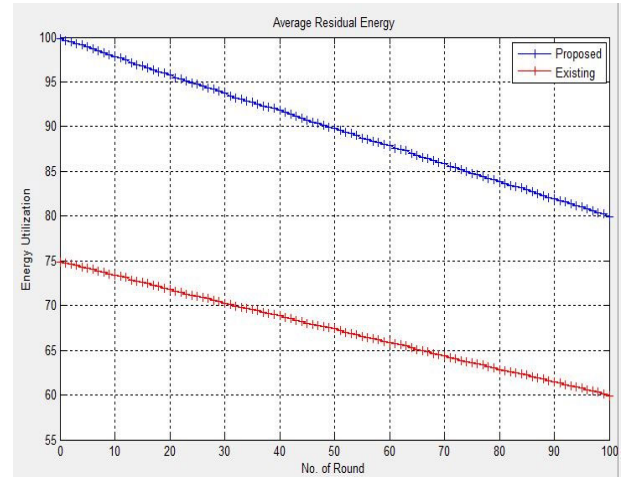


FIGURE 15. Comparison of energy utilization.

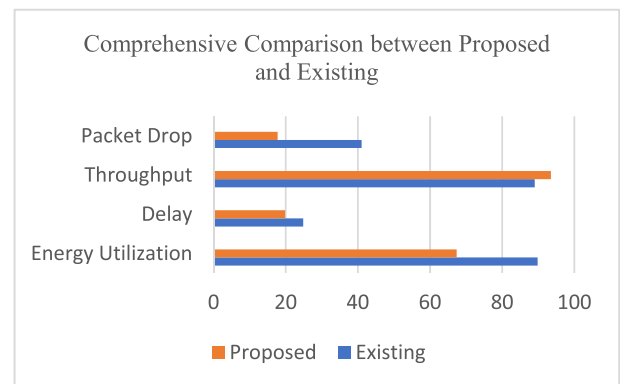


FIGURE 16. Comparison of factors between proposed and existing methods.

the realization of routing algorithm. Whereas the proposed shows 94 % which is more desirable than existing. These outcomes validate that the planned methodology is better relevant for RSU based routing in smart city applications. This framework is proposed for Smart Street and can be used in diverse practice also. Here it is not necessary to find the shortest path at every node. It is visible from the solutions that optimized upgrades the performance of the routing manner under high mobility.

VIII. CASE STUDY

Chaurasia BK et al proposed smart toll payment [38] where automobiles need not to wait for payment. National Highways in India span 6 % of road magnitude at the same time the traffic in the road exceeds 80 %. NHAI (National Highways Authority of India) synchronize and monitor the toll payment. Each motor fleeing via toll has to prepay assured amount corresponding to the motor type, prototype of the road, convention regularity and distance covered. A vehicle is proceeded further in the toll by suspending and settling the tariff. Subsequently, after pay-off the toll port unlocked. This procedure is regulated manually. Approximately hand-operated tariff payment can outgrowth around 300 vehicles for every hour. Traffic is escalated due to the stoppage of

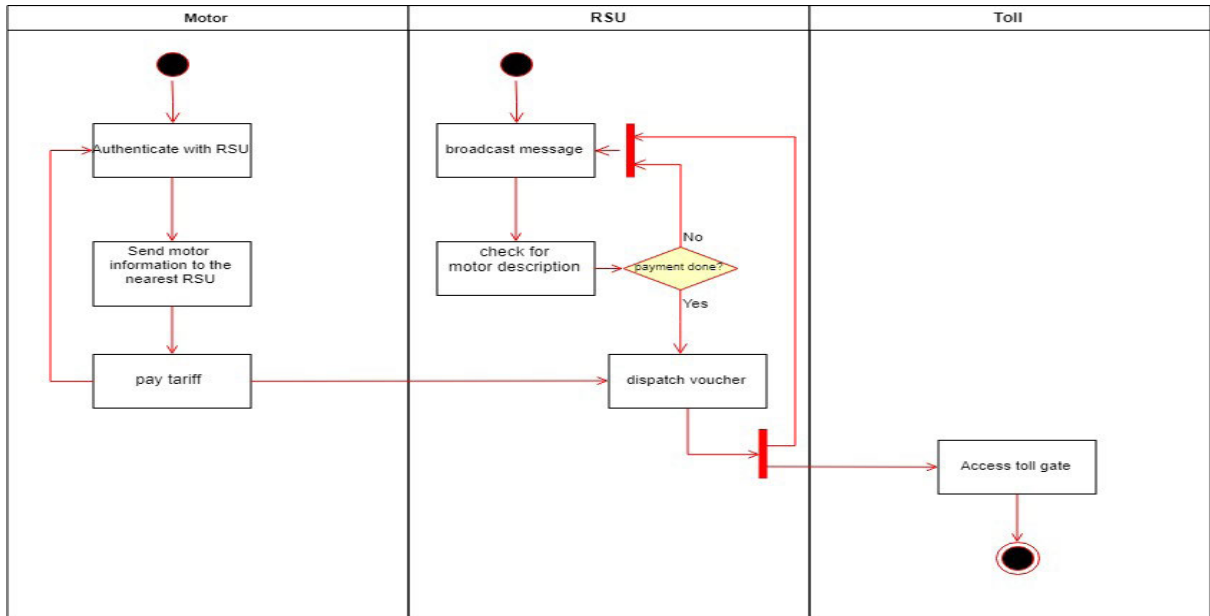


FIGURE 17. Use case data flow in smart toll payment.

TABLE 2. Simulation result for smart toll payment.

Nodes	Total packets delivered	Access delay	Queue delay	End to end throughput
A	6156	0.287238e+02	1.586699e+05	3.229904e+04
B	6150	1.289275e+02	0.626902e+05	3.205192e+04
C	6049	0.330111e+02	1.402770e+05	3.350404e+04
D	6028	0.803201e+02	1.012568e+05	3.654749e+04

vehicles for tax payment. Henceforth the payment is reformed towards online convention. RSU plays a major role in information transposition. Speeding motor communicates with the nearest RSU. RSU is empowered to audit the tariff payment. Motors must accomplish all-inclusive charges within constrained allotment. Thereby upsurge in the framework is achieved by adopting the proposed K-NN based WOA routing approach. The proposed methodology reduces the delay and increases efficiency. The motors must authenticate with the nearest RSU, the prefixed tax is settled and immediately the toll is accessible. The ensuing case study is carried out in MATLAB for 4 RSU and 100 moving vehicles. The mean period taken was 14 ms while the utmost period taken was 26 ms. The toll congestion increases irregularly subjected to the motor speed and density.

RSU broadcast message for tariff acquisition. While motor arrives transmission range of the nearest RSU, it perceives the transmission message. Motor authenticates itself with

the nearest RSU. Once authentication is done, motor sends the description of its status to the nearest RSU. RSU forwards the motor type to the toll monitor. The payment is carried out in a secured attestation. The motor receives the permit to pass toll gate. The toll gate verifies the permit and opens the gate if the credentials are valid. In recent years a lot of approaches are considered and verified on routing for the smart city and this notably acquaints different confrontation correlated to the traditional routing protocols in WSN. Earlier huge time span is requisite for all modules of each application and this also added further cost. The basic objection is to introduce latest devices into the environment. Cities have divergent applications and it is not reasonable to afford in real time. A specific study on Smart Street validates the verification of the recent paradigm. Despite, the focus has been given to the applications where RSU is used predominantly. This prototype enhances the performance under high load and high mobility. Routing is the principal dilemma in the smart city. Quite a few protocols have unfolded to handle explicit problem domains. Furthermore, there are several issues that need to be resolved. The emphasis of added parameters like content relevancy, the speed of mobile neighbours, interaction probability and other metrics must also be estimated. A novel approach is organized around the application of smart cities. Aside from network constrain of different application, all performance metrics could not be validated.

IX. CONCLUSION AND FUTURE WORK

In recent years a lot of approaches are considered and verified on routing for the smart city and this notably acquaints different confrontation correlated to the traditional routing protocols in WSN. Earlier huge time span is requisite for

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REFERENCES

- [1] R. Lu, X. Lin, H. Zhu, and X. Shen, "SPARK: A new VANET-based smart parking scheme for large parking lots," in *Proc. IEEE INFOCOM*, Apr. 2009, pp. 1413–1421.
- [2] J. Jeong and E. Lee, "VCPS: Vehicular cyber-physical systems for smart road services," in *Proc. 28th Int. Conf. Adv. Inf. Netw. Appl. Workshops*, May 2014, pp. 133–138.
- [3] L.-D. Chou, J.-H. Tseng, and J.-Y. Yang, "Adaptive virtual traffic light based on VANETs for mitigating congestion in smart city," in *Proc. 3rd Int. Conf. Digit. Inf. Commun. Technol. Appl.*, Jul. 2013, pp. 40–44.
- [4] C. Sommer, O. K. Tonguz, and F. Dressler, "Traffic information systems: Efficient message dissemination via adaptive beaconing," *IEEE Commun. Mag.*, vol. 49, no. 5, pp. 173–179, May 2011.
- [5] T. Hwang and J. Jeong, "SANA: Safety-aware navigation application for pedestrian protection in vehicular networks," in *Proc. Int. Conf. Internet Vehicles*. Cham, Switzerland: Springer, Dec. 2015, pp. 127–138.
- [6] K. Ota, T. Kumrai, M. Dong, J. Kishigami, and M. Guo, "Smart infrastructure design for smart cities," *IT Prof.*, vol. 19, no. 5, pp. 42–49, 2017.
- [7] X. Sheng and Y.-H. Hu, "Maximum likelihood multiple-source localization using acoustic energy measurements with wireless sensor networks," *IEEE Trans. Signal Process.*, vol. 53, no. 1, pp. 44–53, Jan. 2005.
- [8] O. B. Akan, O. Cetinkaya, C. Koca, and M. Ozger, "Internet of hybrid energy harvesting things," *IEEE Internet Things J.*, vol. 5, no. 2, pp. 736–746, Apr. 2018.
- [9] S. S. Chaudhari and R. C. Biradar, "Resource prediction-based routing using agents in mobile ad hoc networks," *Int. J. Commun. Netw. Distrib. Syst.*, vol. 20, no. 4, pp. 413–445, 2018.
- [10] S. Sharma, S. Verma, and K. Jyoti, "A new bat algorithm with distance computation capability and its applicability in routing for WSN," in *Soft Computing and Signal Processing*. Singapore: Springer, 2019, pp. 163–171.
- [11] S. Yi, P. Naldurg, and R. Kravets, "A security-aware routing protocol for wireless ad hoc networks," in *Proc. ACM Symp. Mobile Ad Hoc Netw. Comput. (MobiHoc)*, Oct. 2001, pp. 1–7.
- [12] Z. Ding, P. Ren, and Q. Du, "Mobility based routing protocol with MAC collision improvement in vehicular Ad Hoc networks," in *Proc. IEEE Int. Conf. Commun. Workshops (ICC Workshops)*, May 2018, pp. 1–6.
- [13] S. Yucel, R. W. Kownacki, and S. Vijayarangan, "Cluster configuration backup and recovery," U.S. Patent 8 484 163 B1, Jul. 9, 2013.
- [14] J.-W. Lin, P. R. Chelliah, M.-C. Hsu, and J.-X. Hou, "Efficient fault-tolerant routing in IoT wireless sensor networks based on bipartite-flow graph modeling," *IEEE Access*, vol. 7, pp. 14022–14034, 2019.
- [15] J. You, D. Lieckfeldt, F. Reichenbach, and D. Timmermann, "Context-aware geographic routing for sensor networks with routing holes," in *Proc. IEEE Wireless Commun. Netw. Conf.*, Apr. 2009, pp. 1–6.
- [16] D. Kumar, T. C. Aseri, and R. B. Patel, "Multi-hop communication routing (MCR) protocol for heterogeneous wireless sensor networks," *Int. J. Inf. Technol., Commun. Converg.*, vol. 1, no. 2, pp. 130–145, Jan. 2011.
- [17] L. Wang, L. D. Xu, Z. Bi, and Y. Xu, "Data cleaning for RFID and WSN integration," *IEEE Trans. Ind. Informat.*, vol. 10, no. 1, pp. 408–418, Feb. 2014.
- [18] L. Chen, S. H. Low, M. Chiang, and J. C. Doyle, "Cross-layer congestion control, routing and scheduling design in ad hoc wireless networks," in *Proc. 25TH IEEE Int. Conf. Comput. Commun.*, Apr. 2006, pp. 1–13.
- [19] T. M. Behera, S. K. Mohapatra, U. C. Samal, M. S. Khan, M. Daneshmand, and A. H. Gandomi, "Residual energy-based cluster-head selection in WSNs for IoT application," *IEEE Internet Things J.*, vol. 6, no. 3, pp. 5132–5139, Jun. 2019.
- [20] K. Keswani and A. Bhaskar, "Flower pollination optimization and RoI for node deployment in wireless sensor networks," in *Information and Communication Technology for Intelligent Systems*. Singapore: Springer, 2019, pp. 165–174.
- [21] T. Ahmad, M. Haque, and A. M. Khan, "An energy-efficient cluster head selection using artificial bees colony optimization for wireless sensor networks," in *Advances in Nature-Inspired Computing and Applications*. Cham, Switzerland: Springer, 2019, pp. 189–203.
- [22] M. Elappila, S. Chinara, and D. R. Parhi, "Survivable path routing in WSN for IoT applications," *Pervasive Mobile Comput.*, vol. 43, pp. 49–63, Jan. 2018.
- [23] D. Jiang, P. Zhang, Z. Lv, and H. Song, "Energy-efficient multi-constraint routing algorithm with load balancing for smart city applications," *IEEE Internet Things J.*, vol. 3, no. 6, pp. 1437–1447, Dec. 2016.
- [24] S. M. Bozorgi, A. S. Rostami, A. A. Hosseinabadi, and V. E. Balas, "A new clustering protocol for energy harvesting-wireless sensor networks," *Comput. Elect. Eng.*, vol. 64, pp. 233–247, Nov. 2017.
- [25] J. Wang, Y. Cao, B. Li, H.-J. Kim, and S. Lee, "Particle swarm optimization based clustering algorithm with mobile sink for WSNs," *Future Gener. Comput. Systems.*, vol. 76, pp. 452–457, Nov. 2017.
- [26] S. A. Jesudurai and A. S. Kumar, "An improved energy efficient cluster head selection protocol using the double cluster heads and data fusion methods for IoT applications," *Cogn. Syst. Res.*, vol. 57, pp. 101–106, Oct. 2019.
- [27] S. K. Lakshmanprabu, K. Shankar, S. S. Rani, E. Abdulhay, N. Arunkumar, G. Ramirez, and J. Uthayakumar, "An effect of big data technology with ant colony optimization based routing in vehicular ad hoc networks: Towards smart cities," *J. Cleaner Prod.*, vol. 217, pp. 584–593, Apr. 2019.
- [28] M. A. Saleem, Z. Shijie, and A. Sharif, "Data transmission using IoT in vehicular ad-hoc networks in smart city congestion," *Mobile Netw. Appl.*, vol. 24, no. 1, pp. 248–258, Feb. 2019.
- [29] E. N. Indra, S. K. Deep, and B. Jean-Marie, "DC4LED: A hierarchical VDTN routing for data collection in smart cities," in *Proc. 16th IEEE Annu. Consum. Commun. Netw. Conf. (CCNC)*, Jan. 2019, pp. 1–4.
- [30] K. Hussain, M. N. M. Salleh, S. Cheng, and Y. Shi, "Metaheuristic research: A comprehensive survey," in *Artificial Intelligence Review*. Dordrecht, The Netherlands: Springer, 2018, pp. 1–43.
- [31] S. Hanif, A. M. Khedr, Z. A. Aghbari, and D. P. Agrawal, "Opportunistically exploiting Internet of Things for wireless sensor network routing in smart cities," *J. Sens. Actuator Netw.*, vol. 7, no. 4, p. 46, Oct. 2018.
- [32] S. H. Ahmed and S. Rani, "A hybrid approach, Smart Street use case and future aspects for Internet of Things in smart cities," *Future Gener. Comput. Syst.*, vol. 79, pp. 941–951, Feb. 2018.
- [33] Y. Miao, Q. Hongbing, W. Mei, W. Yong, and F. Hao, "A new path planning strategy of a data collection problem utilising multi-mobile nodes in wireless sensor networks," *Int. J. Sensor Netw.*, vol. 29, no. 3, pp. 192–202, 2019.
- [34] S. K. Sahana, "Hybrid optimizer for the travelling salesman problem," *Evol. Intell.*, vol. 12, no. 2, pp. 179–188, Jun. 2019.
- [35] Z. W. Geem, J. H. Kim, and G. V. Loganathan, "A new heuristic optimization algorithm: Harmony search," *J. Simul.*, vol. 76, no. 2, pp. 60–68, Feb. 2001.
- [36] P. Salvo, F. Cuomo, A. Baiocchi, and A. Bragagnini, "Road side unit coverage extension for data dissemination in VANETs," in *Proc. 9th Annu. Conf. Wireless On-Demand Netw. Syst. Services (WONS)*, Jan. 2012, pp. 47–50.
- [37] S. Mirjalili and A. Lewis, "The whale optimization algorithm," *Adv. Eng. Softw.*, vol. 95, pp. 51–67, May 2016.
- [38] B. K. Chaurasia and S. Verma, "Secure pay while on move toll collection using VANET," *Comput. Standards Interfaces*, vol. 36, no. 2, pp. 403–411, Feb. 2014.



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