# AN ADAPTIVE QOS SUPPORTIVE ROUTING APPROACH OVER WSN USING BEE HIVE COMPUTATIONAL MODELS – RASCOE

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## ABSTRACT

**Major research works are being carried out towards QoS and route management using WSN. Establishing route depends on various QoS metrics and maintaining session establishment time between end to end nodes which are engaged in communication. Survey on WSN define multiple aspects QoS pertaining to wireless sensor node interference range and packet collisions which results in degradation of network performance and high latency rate. RASCOE discusses on providing consistent QoS with reliable service control which is the major discussion of this research work. RASCOE shows improved performance in high throughput, support on packet delivery rate, and controlled delay. The work suggests on adaptive route management approach based on soft computational models being suggested in the route identification and session maintenance phase.**

**Keywords: WSN, Route management, QoS metrics, bee hive optimization approach**.

## 1.0 INTRODUCTION

An important characteristic of WSN [1] is when the sensor nodes have significant processing capability to compute and categorize their services based on context aware nature of system behaviour. Nodes have to organize themselves, administer and manage the network all together, which is a challenging task to create multi-hop routing and supporting the demandable QoS based on route management. Any change in the physical environment where a network is deployed suggests that a node experience wide variations in connectivity which influences the system organization. The design trade-offs and open research issues [4] are also investigated to point out the further possible research directions in the field of QoS provisioning in wireless sensor networks [22] at network and transport layer.

Understanding QoS in Sensor Network can be analyzed from application-specific [5] and network specific[11]. QoS parameters specific to application in use, as sensor node measurement of service, deployment of node, and coverage and number of active sensor nodes are primary to be adaptive to network. Detailed survey on QoS management and controlling approaches have shown that providing consistent QoS over long period of time is always been a challenge and considered as a misnomer. The challenge lies in variable data delivery rate, session maintenance, handoff issues, route fault management and delivery rate update after the process is complete. Hence the demand for effective route maintenance, hand-off issues in route management is being the focus of this research work. Providing consistent QoS with reliable service control [11] is the major discussion of this research paper. Though metrics such as packet delivery rate, percentile of packet loss, delay time play major role in determination of QoS at any instant of time, providing an end to end QoS over a time session is highly a challenge. Consistent provisioning of bandwidth over the session including hand-off over a hop is major concern under study.

## 1.2 MOTIVATION AND OBJECTIVE

The integrity of data being transmitted and fault-tolerance issues [14][17] in WSN has effect on the performance of any data acquisition system. Noise [2] and other external network disturbances[21] can often degrade the information or data transmitted by these systems. Hence the need for design of an effective QoS route management in Wireless Sensor Networks is a challenge.

As the construction and deployment characteristics of these low powered sensing devices are complex, due to low computation and communication abilities of wireless nodes. Fault tolerant mechanism is inappropriate due to very low computation and overhead of nodes, hence wireless nodes are highly vulnerable to failures. These wireless nodes may lose functionalities at time instance due to energy depletion by harsh environment factors or malicious attack from external senders. Hence optimal QoS at any time period is important for input /output which also decide the survivability of wireless network.

In WSNs, any wireless node that is within another’s interference range trying to transmit simultaneously would result in collisions[8] or packet loss. When collisions occur, retransmissions are required to ensure that the data be successfully received. Such large retransmissions[19] result in additional session control and management. Besides additional session management, extra latency from retransmissions increases the link delay. Because of this extra latency for each link delay, the end-to-end delay from data sender nodes back to the sink node will be increased.

In practical research aspects, QoS guarantees in WSN can be classified as hard real-time and soft real-time systems[4]. Hard Real Time system focuses on deterministic end-to-end delay bound where the arrival of a message after its defined deadline is considered as failure. A Soft Real Time system can support a probabilistic guarantee with an acceptable or tolerable delay. Hence, supporting the RT QoS in WSN should possess either a deterministic or probabilistic end-to-end delay guarantee in order for the system to function with an optimal QoS support [6].

This paper presents an approach to solve optimal QoS approaches with routing approach using Honey Bees Optimization Algorithm. Section-1 discusses on introduction to WSN, need for QoS, route management and role of swarm intelligence in determining an adaptive route. Section-2 elaborates on a detailed survey carried out on WSN and routing approaches for determining an adaptive route for sensor networks. Detailed discussion on the proposed routing scheme RASCOE and need for Bee Hive Optimization approach in Section-3. Section-4 discusses on the algorithm to suggest on implementation of proposed routing scheme RASCOE while Section-5 suggests on experimental approaches adopted to implement RASCOE and Section-6 concludes with performance analysis RASCOE with other routing schemes.

## 2.0 LITERATURE SURVEY

WSN devices are devised to be resender limited, and minimal process capability since they possess low processing speed, storage capacity, network communication bandwidth with limited mobility [5]. WSN nodes are expected to operate for long periods of time, since the nodes are powered by battery, and hence should maintain their energy resenders by limiting their tasks or processes. Mechanisms to control the energy required and support on issues related to minimizing latency issues during transmission and providing QoS on demand is the major task [7].

An important characteristic of WSN is when the sensor nodes have significant processing capability to compute and categorize their services based on context aware nature of system behaviour. Nodes have to organize themselves, administer and manage the network all together, and it is much harder than controlling individual devices.

Researchers has suggested numerous routing algorithms[4], data dissemination / aggregation protocols [3] and power management issues [9] which has been designed for wireless sensor networks (WSNs), being independent on architecture of WSN as well environmental aware applications. A detailed survey on WSN networks architecture, applications and communication protocols insists on understanding the design / architecture of network system, the protocol design factors and requirements of routing, power management issues and data dissemination aspects. Information routing [6] is a very challenging task in highly dense and distributed wireless networks due to its inherent characteristics that distinguish these networks from other wireless or adhoc networks. The wireless nodes deployed in an adhoc manner need to be self-organizing[19] as this kind of deployment requires system to form connections and cope with the resultant nodal distribution. A major design issue in wireless networks is that its behaviour is application specific and determinant on effective bandwidth in use. Hence the application scenario demands the protocol design in a wireless network.

## 2.1 NEED FOR SOFT COMPUTATIONAL APPROACH

Computational models support optimization of real time system [16][20] when the system works in stochastic manner. Determining the unexpected QoS in worst case situations is always a challenge when multiple nodes are stressed into service. WSN nodes exhibit stochastic behaviour where nodes adopt random mobility, and the signal strength is not stable in establishing contact with neighboring nodes.

Soft computational schemes [20] are applied in analysis of complex, stochastic and dynamic schemes whose event and causalities data are unsupervised in nature. Bee Hive computational model [14] do support on multiple clusters and mechanisms to optimize the route capacity based on node behaviour. Detailed survey on cluster algorithms being proposed for generalizing known traffic behavior or change in topological structure of nodes suggests multiple methods to support classifier weakness and methods to boost the WSN system performance based on model combination. Arunkumar et al et.al [3] proposed on a simple and dynamic topological / ensemble model which can suggest on improving the cluster accuracy of nodes publications by combining the probability distribution of several relational attributes and local attributes.

## 2.2 DEFINITIONS

The following definitions are used in this research work to suggest on definition of clusters, nodes associated with variable property, services in use based on network resenders and variables in use.

Definition 2.1.1: Bee Hive optimization approach is defined as a set of points (cells) Bi, interconnected as directed graph with nodes as graph nodes Ni,interconnected by concepts as policies Pi, events whose causalities defined as edgesEi. It represents causal relationship between concepts.

Definition 2.1.2: Nodes of the WSN network are defined as $N = \{n_1,n_2,...n_n\}$ as sets and as well nodes belong to a cluster Ci, where $Ci = \{C_1,C_2,...C_n\}$ where $\{\forall ni \subset Ci\}$ where $ni \in N$ and $i =\{1,2..k\}$ for any k number of nodes.

Definition 2.1.3: Any node ni adopts to edge weights or causalities such as delay D (millisecs), bandwidth in use β(bps), signal strength δ(dbm), node status A and its packet delivery rate (p).

Definition 2.1.4: Any node 'ni' $\in$Ci cluster, iff a node nearness value vector 'τ' $(ni,nj) \leq 1$ and $\delta > 1$. The nearness vector value 'τ' is defined based on the signal strength of the node which plays vital node in defining the neighbour hood property. Neighbourhood property based on nearness value determines the optimal clustering approach for determination of a node in Cluster.

The nearness or neighbourhood property [13][15] exemplifies the intensity of signal strength between the nodes which can be identified based on Hello protocol [8]. Any node which identifies another node can be considered as the neighbourhood node. Neighbourhood property defines that node can communicate with each other using multi-hop approach, such that node 'a' is within the vicinity of node 'b'.

## 3.0 DESIGN OF BEE HIVE FOR ADAPTIVE ROUTING ALGORITHM

Cluster algorithm [23] classifies the WSN node behavior based on accessed signal strength, traffic intensity based on service metrics, observed packet delivery rate into various cluster and sub-clusters. The mobility speed of a node and identifying its neighbor node supports over prediction of variable routes among best available routes while the primary aim is to support on optimized QoS prediction and route establishment based on prediction rules.

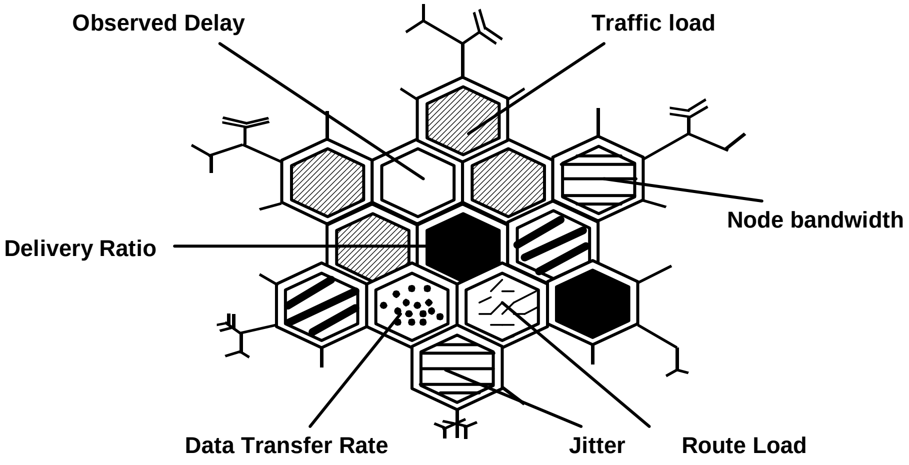

**Fig. 1 Beehive computational model for adaptive QoS over WSN**

RASCOE talks on understanding the node status at an instant of time, route load, rate of data transfer, data delivery ratio, jitter observed in milli-secs, delay observed over period of time, bandwidth of lively node, signal capacity of an approaching or receding node maintained in cluster of bee-hive [12]. RASCOE cluster method exploits the search capability of node the Bee Hive Algorithm as shown in Fig. 1. RASCOE algorithm searches for appropriate cluster and nodes (C1, C2,...,Ck, Cn ) such that clustering metric[10] vi(0) (Eq-1) is minimized. The basic steps of the proposed clustering operation is essentially being implemented out by Bee Algorithm as explained.

RASCOE algorithm requires specific parameters to be set,

'n' : number of scout bees

'm': number of sites selected from neighbourhood search (n visited sites) (m),

's': number of qualified sites among 'm' selected sites (s),

b : number of bees selected for best 's' sites,

'm'–'s' : number of bees recruited for the remaining selected sites

'vi' : initial size of cluster selected for analysis in vector

RASCOE evaluates the sites and bee activity with specific steps as described. Initial vector state v (0) and 'n' nodes can be recognized as

v(0) = (v1(0), v2(0), ….vn(0) ) -------------[1]

where v1(0) defines the value of concept i=1 at an time instant 't'.

1. Initialise the solution population, based on selection of scout bees, re-generation of nectar sources based on Vij = Xij + random (Xij – Xkj ), where i ,k = I, 2, … N and j = 1,2,…N.

rand∈ [0,1] being a random number generated to determine the range of neighbourhood of Xij.

2. Evaluate the fitness of population.

Scout bees determine the quality of food source and distance between the food source and hive being destination.

$$\text{Fiti} = \begin{cases} \dfrac{1}{1+ti}, & if\ ti \geq 0 \\ 1+|ti| \end{cases}$$

3. While ( ! BH [m] )

//Forming new population of bees

a. Select a site for neighbourhood search m = BH[i++]

b. Recruit 'b' bees for selected 'm' sites and evaluate fitness Fi

c. Select the fittest bee 'b' from each site.

d. Assign remaining 'm'-'b' bees to search randomly and evaluate their fitness.

End While

Beehive optimization searches the best possible routes based on the QoS fitness measure [7] to adapt to the system. Analysis of available node metrics determined from activity of nodes and network's system behaviour support on the quality of determining the route and its variable sessions at any instant of time.

### 3.1 FITNESS FUNCTION

Fitness function [6],[7] defined for set of bees measure on the quality of scout bees members of the defined population. The problem can be observed as the quality is measured with the overall cluster accuracy of bees in activity. Hence, for each bee the cluster Cij are identified and its Cluster Optimal Accuracy (COA) determines the fitness function of adopting the bees for task. In the fitness function, the primary aim is to maximize the number of cluster which also maximizes the accuracy and hence minimizes the error rate. The accuracy of a C class problem can be explained using a C x C confusion matrix. The element Cij in row 'i' and column 'j' describes the number of samples of true elements of cluster.

$$COA = \frac{\sum_{i=1}^{n} c_{ii}}{\sum_{j=1}^{i} c_{ji} + \sum_{j=1}^{i} c_{ij}} \qquad \text{-------------[2]}$$

### 3.2 RASCOE APPROACH

RASCOE approach supports multiple WSN nodes for analysis. WSN nodes are classified into clusters based on multiple casual and operational factors of the system in network. If a node changes in mobility speed or direction of motion the signal strength also varies which also determines the signal quality of node and its route with ascertained QoS to be supported.

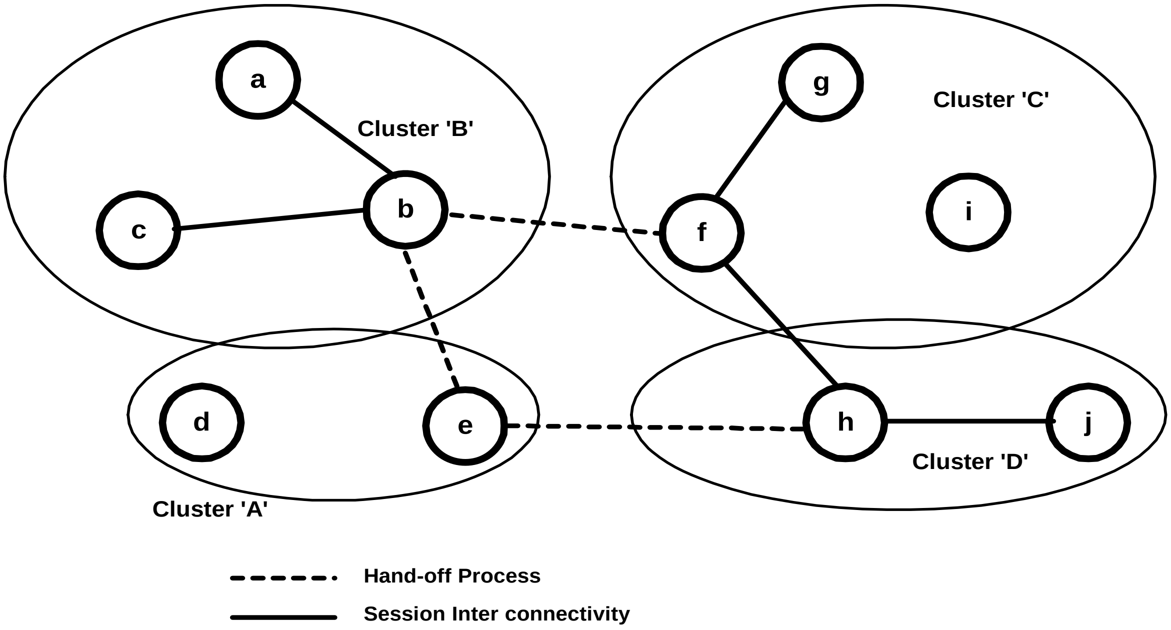

**Fig. 2 WSN nodes cluster based communication**

Fig. 2 shows a set of WSN nodes encapsulated into clusters where a set of nodes 'ni', ni⊂ S and i∈ {a,b,….n}. Here S identifies the universal set of nodes, where a set of clusters Ci is {A,B,…N} and A ⊂ S. Any node 'ni' from a cluster 'A' can communicate with another node 'nj' in another cluster, only if a hand-off session exists between the nodes when establishing the route path.

A group of nodes form a cluster at any instant of time. RASCOE defines any node 'ni' being part of cluster 'Ci' based on 'r' and its signal strength 'δ'. If a node 'nk' does not have the required signal strength to communicate due to its forward mobility, then node 'nk' is considered to be out of cluster 'Ci' while it may belong to another cluster 'Cj'. Node 'b' in Fig. 2 belongs to cluster 'B' which helps in handoff session with node 'e' in cluster 'A' to establish the route path.

### 3.3 RASCOE ALGORITHM

RASCOE approach defines multi-hop route establishment [21] and route selection between any set of sender node and receiver node. Nodes are assumed to be consistently active which tries to establish a communication with one another. All nodes are under random mobility where the mobility speed may differ and its directions may differ [17]. Nodes which identify the neighbourhood node based on nearness property may form a cluster. A group of nodes do form the cluster and all nodes within a cluster identify its neighbouring node.

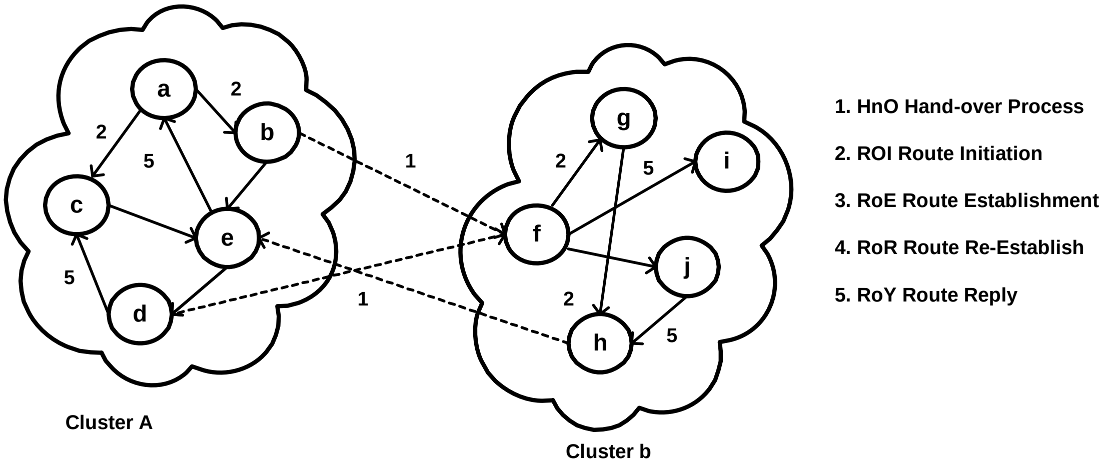

**Fig. 3 Route procedures over Clusters**

Fig. 3 discusses on establishment of multiple clusters Ci for supporting route management and controlling hand-off issues [18] among node based on nearness value ‘δ’. Node ‘a’ in cluster ‘A’ can communicate with any other node ‘b’ within the same cluster ‘A’ or another ‘B’ based on multi-hop route establishment between sender and receiver.

When a node ‘e’ in cluster A cannot communicate with another node ‘j’ which is not within its vicinity hence node ‘j’ is in another cluster ‘B’, then node ‘h’ can be considered as a hand-off node where node ‘h’ should be within the vicinity of node ‘j’ and node ‘e’. Node ‘h’ should be considered as hand-off node as shown in Fig-3. Establishing hand-off between the nodes among multiple clusters demands consistent bandwidth in service and buffer capacity. Any node within a cluster ‘A’ when it needs to transfer data to another node in another cluster ‘B’, the Hand-off process comes into process called as Intra-cluster communication as shown in Fig-4.

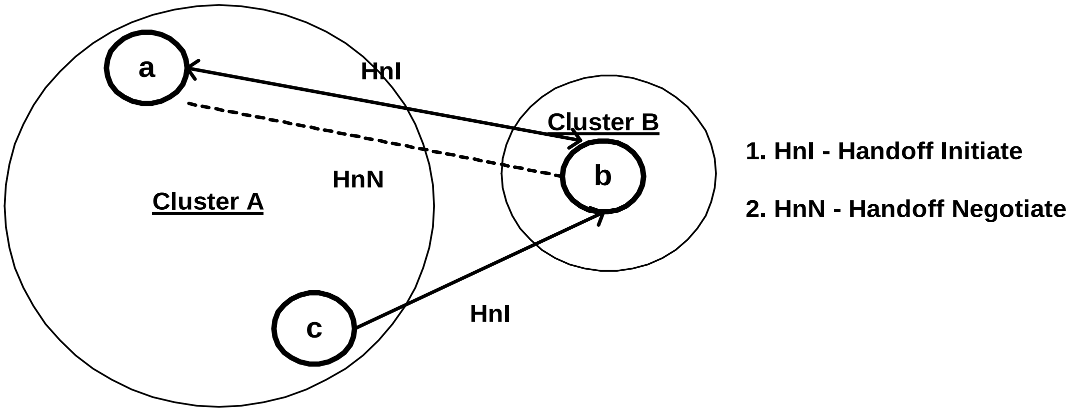

**Fig. 4 Handoff process – Intra cluster communication**

Handoff communication path establised over set of nodes over intra-clusters define the handover initiation (HnI) and Hndoff Negotiation (HnN) process over set of nodes requested and negotiated over available set of resenders. Fig. 4 suggests on number of nodes requested in route establishment process from route initation to route establishment from sender to receiver set of nodes.

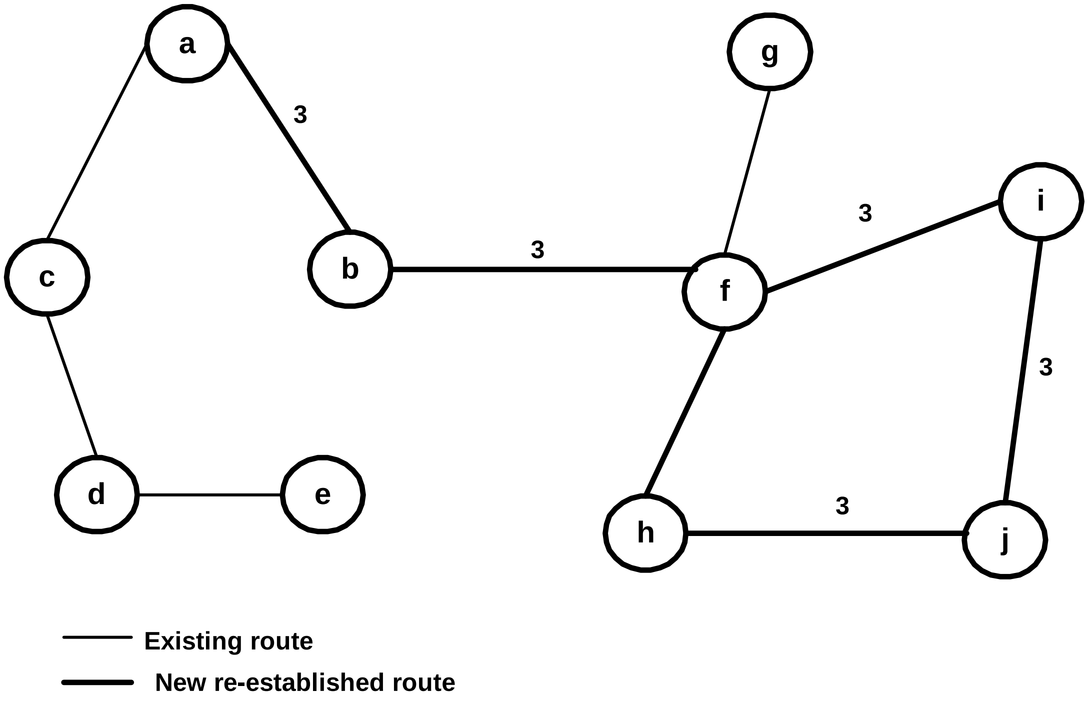

**Fig. 5 Route establishment procedures**

RASCOE algorithm works on three functions. Three major functions are carried out by any generic routing protocol – identification of new route (RoI), selecting an optimal route among the available routes and perform route establishment (ROE) and update for data transfer(ROR). Same functionalities are also incorporated in RASCOE by implementing features like route re-establishment and route reply. Fig. 5 shows the message flow of RASCOE which indicates the simplified execution flow of the algorithms. The RoI and RoY packet contains three more fields to accommodate QoS parameters such as bandwidth, delay and packet loss, in addition to the required fields for transferring data.

A sender node initiates a route discovery to the receiver by sending RoI packets towards its neighbours. As soon as the RoI packets are received, the neighbour or the receiver will process those RoI packets. If the neighbour can satisfy the QoS requirements, which forward the RoI packet to the next neighbouring node or receiver node.If the receiver node has not received the RoI, which responds with a RoY packet to the sender.

When a node receive a RoY packet, if it still has the required resenders available, it creates a forward route entry to the receiver, reserves the required resenders and then forwards the RoY packet to the upstream nodes using the reverse route. When the sender receives the RoY packet from the receiver, it will create a route to the receiver in the routing table. Subsequently, the data transmission to the receiver is initiated by the sender.On the other hand, a node that receives a RoY packet, and does not have enough resenders to satisfy the data transfer, may drop the RoY packet and generate a RASCOE_ERR packet, as well re-send back to the node from where it is received the RoY packet.

Procedure RASCOE Adaptive Route

{ Route_Create (Route_ID, Route_Next, QoS_value) }

Route Request (RoI) and Route Reply (RoY) for any node Fi

Variables:

S, D : Identity of sender and receiver WSN nodes

Route [ ] :Routes assigned as array holding all set of WSN node

Route_OPT, TempRoute : Optimal route and temporary routes from S to D

η: WSN Node selected for route transfer

|Hopk|: ‘k’ number of hops between S to D, where ‘k’ being the signal and radio

propagation length

Ri (Li, Fi) : Route segment where neighboringWSN node Fi is located

Bi :Buffer on Hold for a session “i”

$\delta$: Route update Time

RoI: Route request packet

RoY: Route reply packet

Hno: Hand Off Node

```
RASCOE_ Optimal Route Selection ( )
Upon receiving RoI( S, D, TempRoute) from any Fi
1: if (S == D) & (|TempRoute| ∈Route) then
2: Route_OPT = TempRoute
3: Send RoI( S, D, Route_OPT )
4: return Route_OPT
        5: RoI← Route [ ]
else
6: return RASCOE_RER ( 0 )
7: end if
8: if RoI≠ θ
9: if ( Ri ( Fi ) ≠ Ri ( Fj ) & ( Ri( Fi ) ⊂TempRoute ) then
10: add Ri( Fi ) to Route [ ]
11: end if
12: set Hop k = distance( Fi , Fj) * δ   /* internal node distance  */
13: increment Hopk
14: endif
15: if Ri( S ) == Rj( D ) then
16: stop Hopk / * Fi is a better broadcast node */
17: end if
18: set η= 0                    /* adaptive route discover  */
19: RASCOE_RoE Route ( S, D, TempRoute ) /* route establishment */
20: receive RoY( D, S, Route_RPL(Fj-1,Fi-1,-1)) from Fj  /* route reply  */
21: if η≠ -1 then goto step 8
else
22: continue
23: if ( Fi == S ) then
24: Store Route_RPL in Bi
25: Forward RoI (S, Fi, ROUTE_RPL(Fi+1, Fj+1,D, η))
26: end if
```

RASCOE algorithm explains adaptive route establishment based on route discovery and establishment among large number of nodes in activity. Algorithm identifies multiple routes between any set of sender and receiver nodes. Node ‘a’ may be the sender node and node ‘j’ may be the receiver node where multiple hops may be suggested between nodes involved in data transfer. Algorithm suggests on route discovery and re-establishment when any mobile node moves away at a variable speed or change in direction. Based on node mobility, change in direction and signal variation any existing node which may be waiting for the next hop to receive the data may lose it connectivity hence route establishment needs to take place.

## 4.0 EXPERIMENTAL TEST BED

To prove the efficiency of RASCOE, SPIN and LEACH have been adopted with swam intelligence optimization approaches. The system is compared with Bee Hive Colony algorithms and recent variant of Ant Colony Algorithm. To test the performance of swarm intelligence algorithms the system formulates the following metrics to experiment under the settings:

Bee Colony size NP = 50

$\varphi_{ij} = \text{rand}[-1, 1]$

Number of food sources SN = NP/2

The number of simulations/run =100

The stopping criteria is either maximum number of function evaluations (which is set to be 200000) is reached or the acceptable error has been achieved. Parameter settings for algorithm is set based on survey and original research papers.

## 4.1 SETTING UP THE EXPERIMENTAL TEST-BED

The experiment is carried out with 25 nodes using a simulated test-bed with varying mobility speed, direction, distance between inter communication nodes as shown in Table 1. ns2 simulator is used in analyzing the performance of RASCOE. The experimental approach suggests working on ns2 simulator where the simulation metrics run on variable nodes of 10 to 200 nodes in activity. Simulation experimental setup focuses on variable node intensity which may include wireless sensor nodes and gateways. The simulation area adopted for the experimental area includes a square of 500m x 500m with the radio transmission range of 250m.

| Simulation parameter | Value | Simulation parameter | Value |
|---|---|---|---|
| Simulation time | 500 s | Number of sensors | Between 100 and 200 |
| Number of networks | 20 | Collusion | Yes |
| Simulation field | 500 ×500 m | MAC protocol | TMAC |
| Mobile object inter-arrival | 5 | Routing protocol | Multipath routing protocol |
| Sink distribution | Poisson | Sensor distribution | Gaussian |
| Packet rate | 250 kbps | Maximum MAC | Frame size 2500 |
| Radio bandwidth | 25 MHz | Modulation type | PSK |

**Table 1 Simulation parameters**

## 4.2 EXPERIMENTAL STOPPING CRITERION:

The algorithm checks on optimization procedure, the fitness value and can be stopped when the error can be less than 0.001 times of the required minimum of one and global optimum. If the optimum value is zero, the procedure should stop and if the solution was different from optimum value by less than 0.001.

## 5.0 PERFORMANCE ANALYSIS

The performance analysis of RASCOE approach over other routing schemes and algorithms is discussed in this section. The analysis primarily support on major metrics related to supporting consistent QoS support over the session. Packet delivery rate is a major metric which works on the percentile of packets ( in bytes) delivered to the receiver node and initiated from the sender node. Literature survey shows that Packet delivery rate should be the maximum to determine the optimal QoS over any instant of time ‘t’ also defined as throughput.

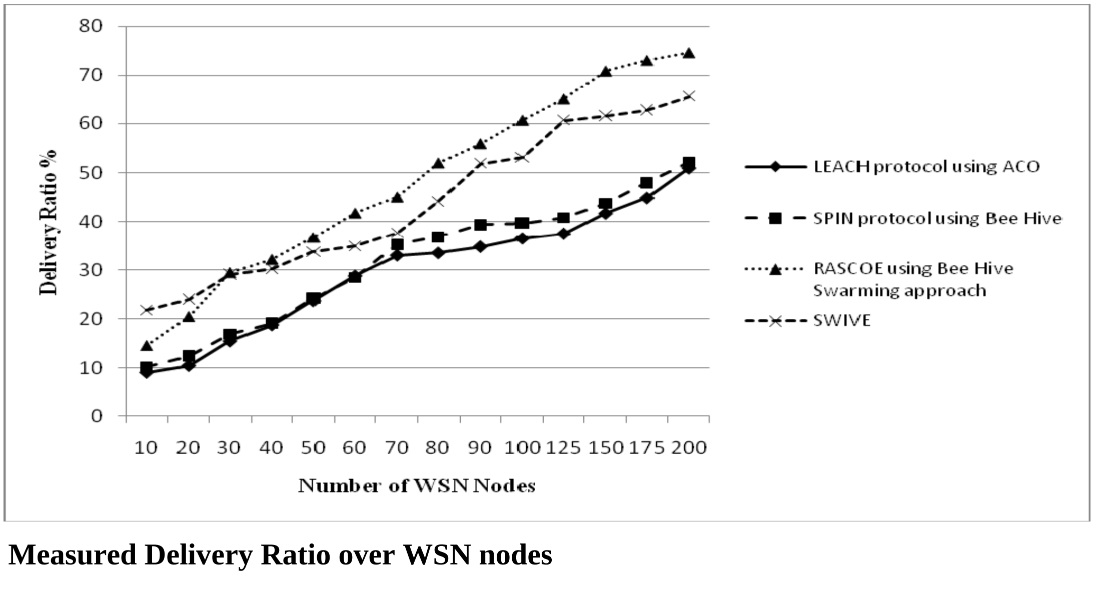

**Fig. 6 Measured Delivery Ratio over WSN nodes**

Fig. 6 shows the packet delivery rate of WSN routing schemes such as LEACH, SPIN over ACO swarm intelligence approach and Bee hive approach. Performance of RASCOE is compared with LEACH, SPIN and SWIVE which supports a higher delivery rate over large number of nodes. RASCOE suggests its traffic behaviour based on number of nodes engaged in communication and multiple sender and receiver nodes. With minimal number of nodes SWIVE suggests a higher delivery rate but when the number of nodes involved in communication increases above 70 nodes, RASCOE shows a higher delivery rate. The bandwidth involved in establishing the communication between nodes is found to be optimally utilized than SPIN and LEACH schemes. RASCOE shows higher delivery rate with an average of 75.27% compared to SWIVE with 64.93% and SPIN with 48.50% and finally LEACH routing scheme.

The observed throughput of RASCOE is shown in Fig. 7, where the data transfer rate of number of sessions determines the maximum throughput. RASCOE which adopts bee hive swarming approach shows higher throughput of 11040 bps when compared with SPIN and SWIVE which shows 9053 bps on average with LEACH whose throughput is 6090 bps.

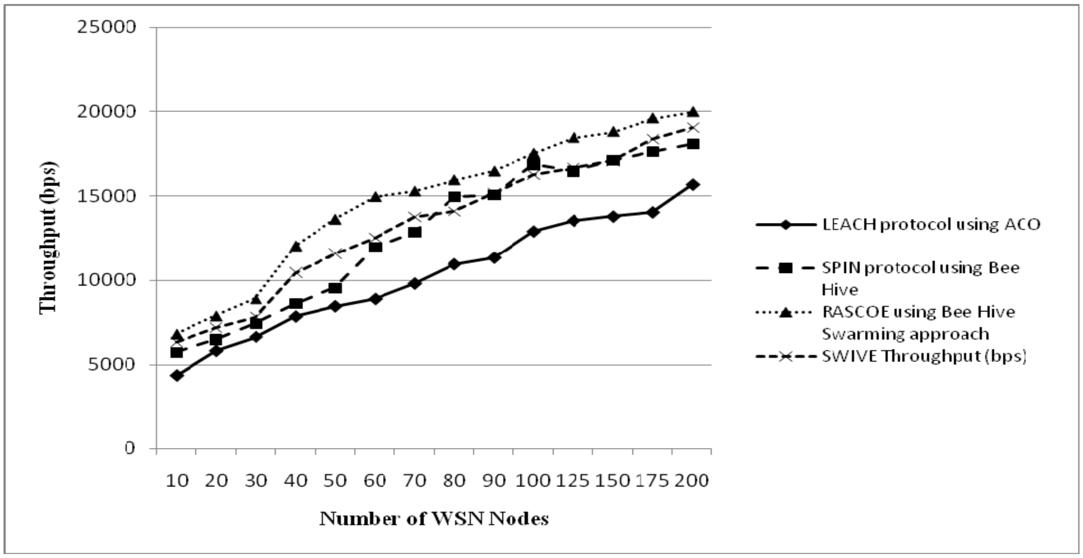

Fig. 7 Observed Throughput over WSN nodes

Fig. 8 shows the overall observed delay of RASCOE with other routing schemes where performance of RASCOE shows minimal delay with an average of 1104 ms compared to SWIVE whose performance delay is 1856 ms while SPIN shows 2884 ms and LEACH shows 4405 ms.

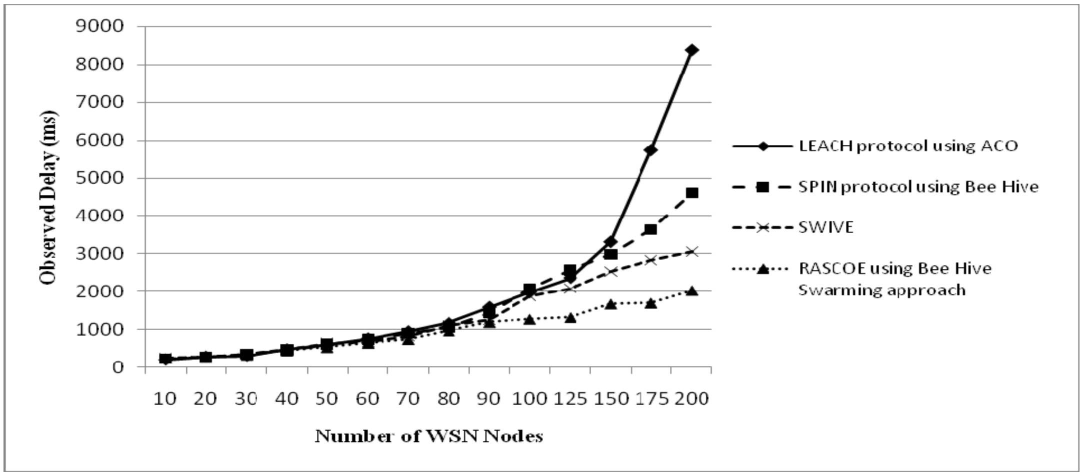

Fig. 8 Observed delay of RASCOE with other routing schemes

The overall performance of RASCOE demands on supporting consistent QoS with variable number of nodes in activity. An optimal support on providing required bandwidth, data transfer rate inspite of variable mobility, direction of node, and service rate in use is highly demanded in research prospective. RASCOE supports the nature of network inspite of variable demands and provides an adaptive routing support.

## 5.0 CONCLUSION

Route establishment and consistent QoS maintenance over highly disrupted channel is the major challenge lying in front of WSN researchers. Survey and conduct of research in this domain had not been highly fruitful due to change in environmental conditions and feeble bandwidth supported by the network. Hence providing a consistent good QoS on long duration of time needs to be discussed in terms of experimental approach over large number of nodes in activity.

Two major WSN protocols are considered for analysis along with SWIVE which can be considered due to its support for large number of nodes. The algorithm works on providing consistent bandwidth demanded for the service in use. Effective handoff mechanism is also a demandable support in RASCOE, where identifying the adaptive route is the primary objective of this research work. RASCOE shows better performance compared to SPIN, LEACH and SWIVE schemes in terms of optimal QoS metrics as per the discussion in section 5.0. RASCOE algorithm can be highly recommended for large WSN networks which are highly dynamic in nature, whose node status is variable and hence suits for different environmental applications.

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