ARANO: Design of an Adaptive Route Management Approach with Support for QoS over IoT Networks

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Abstract-Quality of Service (QoS) for which depends on service based applications is a research challenge, lying as a major demand among the developmental and research community. ARANO suggests on a route supported adaptive route scheme which specifies on route discovery, establishment of session and data transfer approach. The demand on need to capture transient abnormal events reliably and detecting life threatening critical disorders normally go un-detected since it happens only infrequently. ARANO, an adaptive routing approach is the primary objective of this research work which support on design and implementation of IoT components as objects, the experimental test-bed is designed which supports on liveliness of human beings towards health care development. Performance of ARANO towards QoS metrics shows that throughput, delay and packet delivery ratio behaviour is well measured and analyzed as part of research work.

Keywords: IoT, QoS, NTSC, Adaptive Route Management, PDA

I. INTRODUCTION

Most of the messaging protocols and routing approaches directly work with sensor components and microcontrollers to push the message [4] as a forwarding method to transfer the data from a IoT device to another IoT device irrespective of its routing mechanism incorporated between the nodes and centralized gateway to cloud. This approach creates latency among the nodes towards data transfer and this lacuna reduces the QoS factors to be supported for a service.

The proposed scheme ARANO suggests on a route supported adaptive route scheme which specifies on route discovery, establishment of session and data transfer approach. This approach also selects an alternative path for routing instead of an incremental route normally adopted by traditional schemes [7] such as SPIN[8]. The proposed model is also helpful in route / session management and controls on error handling approaches which is not well taken care in RPL [12] approach. ARANO can work on critical Internet of Things service based applications with demandable QoS metrics.

Healthcare applications require processing of time sensitive data, maintaining the context relation as well as transmitting the health details of patient through a reliable, distributed, robust system[9], which necessitates playing an important role for a real-time application. The primary objective is to develop a fugitive approach for deterministic and optimized model along with efforts to balance the available resource constraints which is the major constraint. In order to support on design of an adaptive decision making and deterministic setup, most of WSN networks employ intelligent agent based approach such as Ant Colony Optimization or Swarm Intelligence Techniques [10], which provides global optimal solution over a varied search space which is always required. This work focuses on design and development of an agent based approach to provide robust, low cost, improved information efficiency, reduced latency, task prioritized, with increased device application lifetime system for health care supportive system which works on ARANO, an adaptive routing approach. This research work does support on design and implementation as well as support to liveliness of human beings as part of smart city. ARANO module works on with online data system which collects the patient's data, process it and maintain it in repository system such as cloud. Such maintenance of streaming patient data sets will help on technical phenomenon of big data analysis using machine learning and support towards intelligence.

A. Support for Healthcare using IOT

The project works on providing diagnostic support for patients in hospital[9] or at any living space where the patient can carry out regular tasks as well as can be concurrently monitored. Phenomenon of monitoring the human body related to medical diagnosis where information and communication technologies are integrated such that two different interdisciplinary subjects of relevance can be used to support the design, development and working of the component.

Need for consistent monitoring and maintenance of health care among patients and elderly people lead to the demand on change in traditional monitoring approaches among chronic disease patients and alert on acute events. The demand on need to capture transient abnormal events reliably and detecting life threatening disorders normally go un-detected since it happens only infrequently. Stress on better diagnosis and support on treatment with monitoring are possible through communication systems enabled with WSN or WBANs. Such approaches shows promising results in monitoring of patients after surgery, during rehabilitation, after assessment of daily life activities among elderly people or people suffering from cognitive disorders like Alzheimer, Parkinson's or similar diseases.

The objective of this research work is to design and development of monitoring and warning support health monitoring system that comprise of a compact body worn device (embedded on a garment) over a patient, as a network connected with web server and mobile network with internet as shown in Fig. 1. This research work focuses on developing an innovative model for an integrated Medical, Healthcare, and Emergency using Internet, wireless, multimedia, and real time technologies.

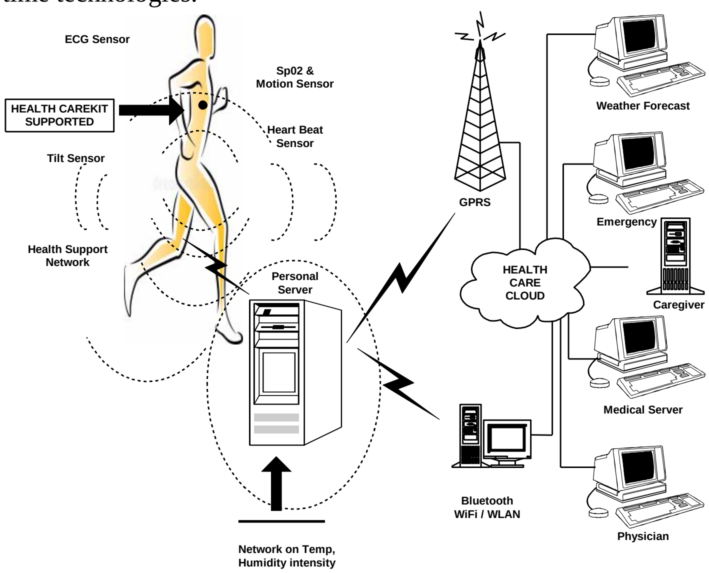

Fig. 1 Health Care Functionality using IoT Objects as Nodes over ARANO

The work focus towards investigation of providing optimal Quality of Services (QoS) on routing issues over wireless Internet connected Sensor networks(IoT)[2][5]. Defining an adaptive reliable QoS over IoT networks with extendable support over cloud and event delivery (ARANO) is always a challenge. ARANO supports over multi-scalable architecture for delivery of quality of services in streaming data for group communication services or applications. This work proposes QoS supportive architecture with optimal QoS service over routing with test bed implementation using real time test bed approach.

II. RELATED REVIEW

Sourabh Bharti et.al [11] suggested a WSN based offline health monitoring system based on radio active and passive positioning approaches. Martin and D. Raskovic [10] had proposed a novel approach based on fuzzy regular formal language to formulate the knowledge of health state thorough wireless health monitoring system, which adopts the health symptoms as ambiguity and causal relationships between various health disorders. Symptoms are adopted to understand the health condition and define a thorough estimation with a certain degree of confidence interval. Krishnamachari et al [6] suggested the usage of mobile web to enhance patients' facilities, which works on basis of W3C web standards. This approach permits the patient to access their account from any mobile phone with capabilities of connecting to the Internet. Oladayo Bello and Sherali Zeadally [10] suggested a prototype model of health care system using open source technologies for maintenance of centralized, medical patient records which can be viewed, consistently updated by experts or physicians using java script enabled browsers. A Taiwan based research team had developed and implemented a home tele-care system for integrating various biomedical sensors which includes channel Electrocardiogram (ECG), Blood Pressure (BP), including images to be transferred onto a National Television Standard Committee (NTSC) channel for communication to be established between patient and doctor as healthcare provider [8][14].

III. ARANO

The demand for an adaptive QoS routing for highly volatile sensor supported IoT networks is requested by service community. Research community has been working in this domain over the past decade towards QoS and routing solutions. Though RPL, MQTT [1], CoAP [1] protocols work specifically on route metrics, and flow control mechanisms [13][15] these approaches do not consider on congestion control and other related QoS metrics. ARANO defines numerous valuable definite sensor nodes placed on spatial locations whose activity is based on event detection. Any sensor node is activated based on an event call or detection, as well as sensor goes into sleep mode if not in use for a defined time interval of 10 secs, hence which preserves the battery consumption. Any IoT component / node identifies its neighboring IoT node based on "adjacency" mechanism of Hello protocol [4] request and reply procedure.

A. Design suggestions

The spatial locations of placing the sensor node on body, determine the efficiency and accuracy of node transfer and analysis[5]. Placement of sensors apriori by research ecologists [9] to ensure data transmission, which collects the data, can be represented as major supportive parameters for deployment of node on buildings, body, forest locations based on the physical constraints. The node and network connectivity suggests on system performance and deployment[7]. Fig. 2 shows the route discovery process for ARANO which involves the "active nodes" involved in counseling the route discovery process. Each route discovery process involves multiple nodes, which inter-operate to understand the status of nodes. Each node suggests on its usage, bandwidth in use, processing capability and buffer capacity on hold.

Algorithm ARANO is built into two major modules, (1) Node and Route Discovery (2) Route selection where all active nodes inter-cooperate to form route based on traffic intensity, buffer on hold, node status and congestion intensity. Alternate routes are selected if any intermediate node fails or optimality value of a route is altered during route selection.

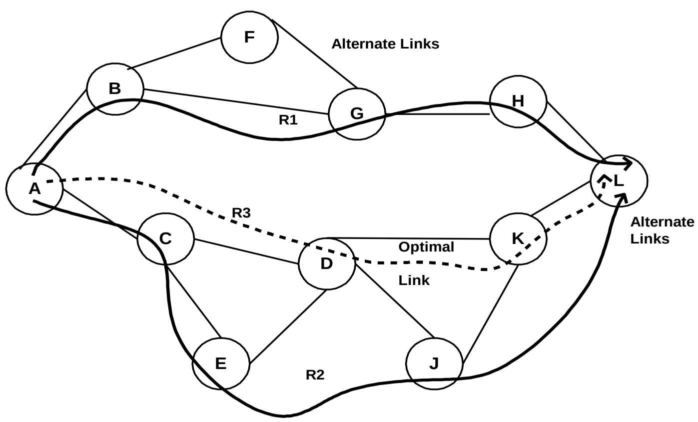

Fig. 2Discovery of Routes and Selection

Algorithm ARANO_Route_Selection ( )
Optimal routes inter-connecting IoT node defined as Components or Objects
Input : Given node set G = { G_1 ,G_2, ⋯ ,G_n }
Traffic intensity = T_i, Node Status S ={A,L,U} // active, Sleep, Not in Use
Distance between nodes = d, Coordinator node = C

Output: Optimized route selected connecting active nodes under constraint.

1: for each pair of nodes u and v where u ∈ G_i, v ∈ G_j : 1 ≤ i and j ≤ d do
2: compute all possible shortest Euclidean path between u and v for
'd' constraint
3: assuming each node in group G, having a coordinator node based on maximal node
communication range
4: for each pair of coordinator node C in G_i and G_j in G where i < = j
do
5: compute the minimum Euclidean path under node density constraint between G_i
and G_j,
i.e. ,d (G_i∼ G_j) = min{ d(u,v) :∀u ∈ G_i , ∀ v ∈ G_j }
6: using Prim's algorithm to find a MST under hole- constraint to connect all C nodes
which are within communication range of a cluster.
7: for each component which contains atleast minimal node status = 'A' do
8: find a shortest path under hole-constraint connecting itself to the nearest RNs (maybe
use some new deployed RNs).

ARANO_Route_Discover() identifies all possible routes from assigned source to sink or gateway. The source node checks status of each neighboring node and requests using REQ( ) message to participate in routing. The REPLY( ) message returned by node indicates node status as well as willingness to participate in route transfer. A three-way handshake procedure [3] is adopted before the process is completed towards initiating the route process. This procedure identifies all possible nodes before performing route transfer.

```
ARANO_Traffic_Value := Channel_Bandwidth_In_Use
ARANO_Value := 0
Service_Type :=0 // Request for a service

Step a: Is ARANO_Node_Status= "ACTIVE" and
        Route_Status= "TRUE"
        Add_Route ( ARANO_Route_Selection [ ])
      else
        Refresh_Route ( )
        ARANO_Value :=1

Step b: // determine congestion value
     Is ARANO_Route > ARANO_Congestion_Value
     {
        Update_Route ( )
        ARANO_Value :=1
     else
        Step a,c ;
```

```
    }

Step c: Is Traffic_Type ( ) > ARANO_Traffic_Value
        and Service_Type ( ) > ARANO_Value
      {
      // check for priority
        Assign_Route := Traffic_Priority_Handler ( )
      }
      else
      {
        Assign_Route := Normal
        Assign_Route_Intensity := ARANO_Weight
      }
      Update_Channel_Coordinator ( ARANO_Route [ ] )

Step d : Channel_Create ( CC [ ])
      {
        CC ( Node_Bandwidth , ARANO_Route [ ],
Traffic_Type,
            ARANO_Weight, Service_Type [ ] )
        Update_Channel ( CC )
      }
```

ARANO_Route_Selection( ) selects the optimal route for transfer adaptively at any instant of time during transfer process. The optimal route being selected is dependent on node variable status, traffic intensity over a link at any instance, distance between the nodes and bandwidth of nodes participating in route.

IV. EXPERIMENTAL APPROACH

ARANO adopts wireless / mobile sensor which defines and incorporates multiple small, lightweight sensors [13] that are used to be placed on the patient's body. These sensors absorb consistently and transmit the level of blood pressure, heart beat rate, level of oxygen (SpO2), body temperature from patient to a web gateway server using GPRS.

ARANO can be built into a multi-tier system architecture as shown in Fig. 3, where the lowest level encompasses a set of data collection sensors, the second level is the personal server (Internet enabled PDA, cell-phone, or home computer) and the third level encompasses a network of remote health care servers and their services such as from Caregiver, Physician, near by clinic, Emergency support, and weather forecast to support on patient health condition. Increased system processing power allows sophisticated real-time data processing on sensors, which reduces the wireless channel utilization and energy consumption. This Health Care unit adopts a WiFi /WLAN support with components of off-the-shelf sensor platforms and application-specific signal conditioning modules.

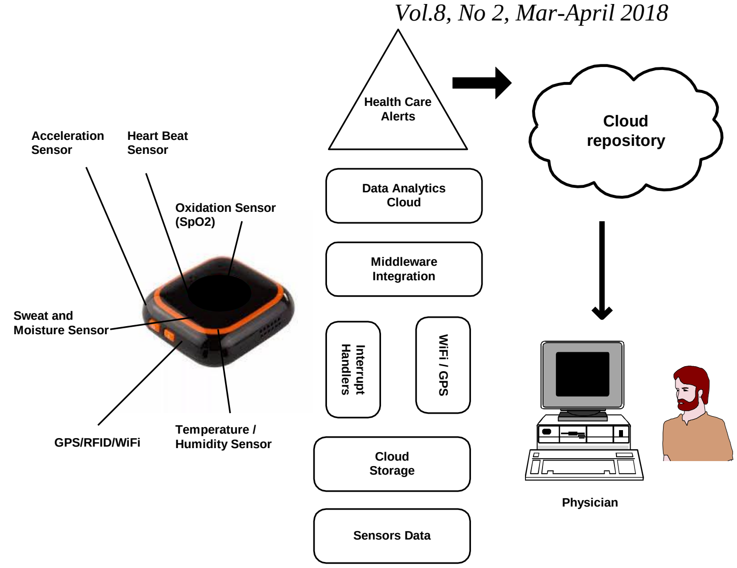

Fig. 3 Architecture and Prototype Module of ARANO

Table 1 SIMULATION SETTINGS

Component Descriptions	Experimental component
Micro Controller	STM32f405-ARM, 32-bit-Cortex-M4-CPU with FPU
Flash memory	1 Mbyte
Low-power operation	Sleep, Stop and Standby modes-VBAT supply for RTC, 20×32 bit backup- registers + optional 4 KB backup SRAM
Radio and Wireless Range	TI CC2520, Outdoors range - 150m with 3dBi antennas based datasheet: up to 400m
Routing Level	RPL, CoAP based on border router
Radio Duty Cycling	Channel check rate is set to 4 Hz
Sensors	Temperature/humidity sensor (SHT15), Heart Beat Sensor, light sensor (MAX44009), Oxidation sensor(SpO2), Acceleration sensor (ADXL346) / Tilt sensor, Sweat and Moisture sensor (optional), Interfaced with IRMote-CC2520 using an I2C bus (Sensor Port)
Radio Transition Rate	30 meter -1dBm in simulation and 2 meter in experimental approach
Power in Use	2 AAA batteries (3.3 V to 5 V)

The Health Care supported kit supports on IoT standard network, where Network Layer is supported with IPv6 over 6LoWPAN standards 802.15.4. Application Layer is defined as anIR-Interface with RPL/CoAP/MQTT and

ARANO (proposed) protocols. The experimental setup supports on 70 randomly-deployed nodes with a warming time of 120 seconds for sensors to initiate and deploy during runtime emulation. The data is generated for every 20 sec and 30 sec over UDP packets and the setup is simulated for 2 hours execution time. ARANO (Fig. 4) is implemented on both client nodes and server node to check resource discovery and route transmission. The data is gathered over cloud which could be predicted by medical experts on patient's or elderly person support.

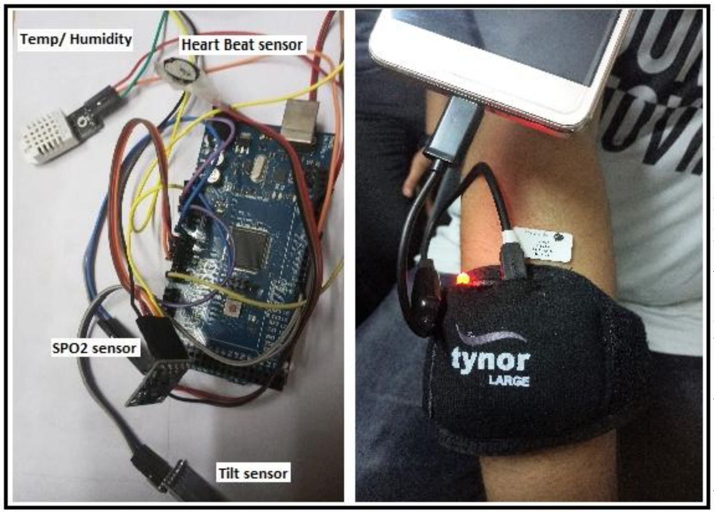

Fig. 4IoT Client Module and ARANO Module with Support for Routing, QoS and Data Collection

The performance of ARANO is discussed for 90 nodes which are being emulated. The data gathered for 70 nodes is simulated using C++ for any extendable IoT components as nodes. Though the number of nodes is increased, one server or gateway is used to receive the data stored as repository in cloud.

V. PERFORMANCE ANALYSIS

ARANO discusses the performance of TCP and UDP over IoT network scenarios from multiple clients which adopt "limited mobility" being fairly well-studied and discussed. The studies shows that the measurement metrics have attempted towards characterization of IoT / wireless network performance from mobile nodes, such as a patient fixed with sensors, internal processing abilities. ARANO's behavior of node inter-connectivity are initiated over an IEEE 802.15 channel and measured over real time health care supportive kits installed on a patient moving in different directions. This study involves a small number of bi-directional measurements over both UDP and TCP over RPL, TOPSI, ARANO for service based applications.

The performance achieved over data transmissions using RPL protocol, TOPSI protocol, and ARANO QoS is based on the following metrics:

(a) End-to-End Delay: The average time difference observed between the time taken by service packets being generated and received as the time of arrival at their destination.

(b) Packet Delivery Ratio (PDR): Defines the percentage of packets successfully received at destination node. PDR refers to the ratio between the number of successful transmissions and the total number of packets generated at source.

(c) Throughput: The rate at which data moves from one node to another, including the effects of data-compression and error-correction protocols. When the number of registered nodes increases, a single Mobile gateway can serve more nodes resulting in relatively lower throughput for ARANO. The performance of hybrid proactive scheme (ARANO, TOPSI) was observed to be slightly better than the pure proactive scheme (RPL).

Throughput of IoT nodes engaged in route transfer over the simulation period is discussed in Fig.5. The nodes which are active in an existing communication over a route transfer cannot participate in another new request for transfer, while if the ongoing route transfer process is completed then the nodes can issue a new status request based on which the resources are identified and can participate in route transfer process.

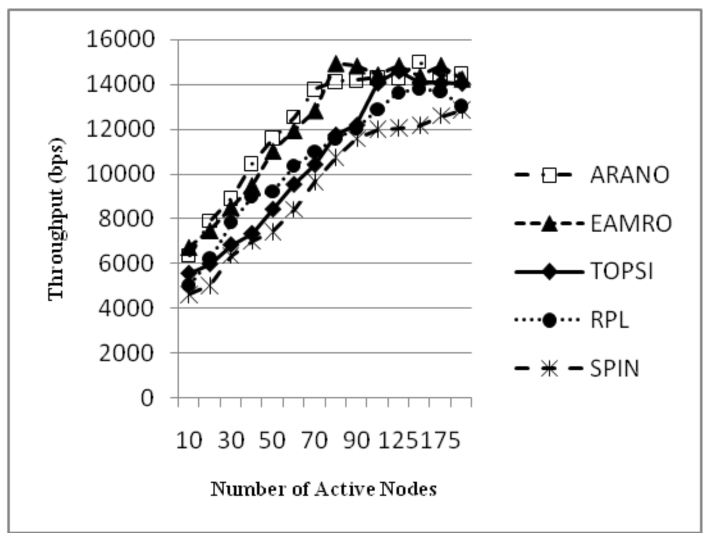

Fig. 5Throughput Observed in ARANO over Traditional Route Approaches

The observed throughput in each session is based on node interaction and route establishment time. ARANO shows 36.2% of higher throughput compared to RPL, 47.94%

higher than SPIN and 12.83% higher than EAMRO scheme. ARANO shows similar to EAMRO until 40 nodes are added in experimental testbed. The performance of ARANO's throughput is higher in terms of number of active nodes against number of sessions handled and packets received.

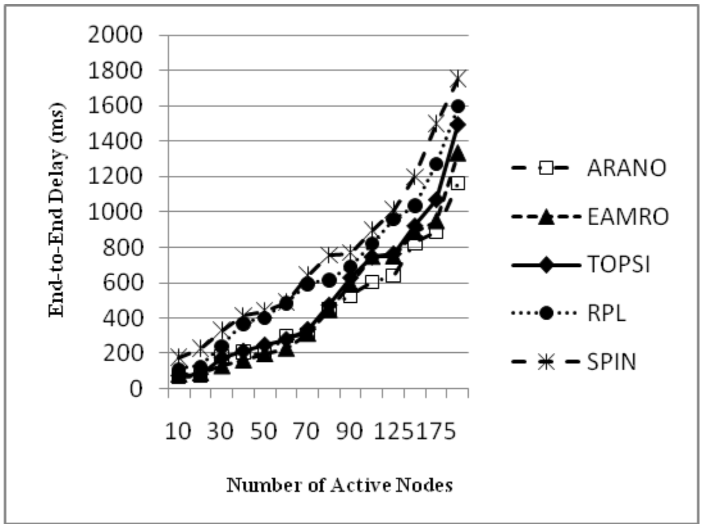

Fig. 6Observed End-to-End Delay over IOT Networks

End-to-End delay observed over IoT nodes is shown in Fig. 6. Here, SPIN shows a higher end-to-end delay of 872 ms, followed by TOPSI, EAMRO and ARANO which demonstrates similar delay varying between 70 ms to 1000 ms for variable nodes activity. This performance negotiates on traffic intensity or link capacity as a major metric in route assignment, a link for data transfer. When maximum number of nodes participates in route establishment, additional time is consumed for route negotiation, resource discovery and node update.

Fig. 7 discusses on observed packet delivery ratio which is a major defined metric to predict adaptive QoS based on variable services in use and node activity. Any node which enables its activity from initiation of session to complete transfer of an established session is being part of analysis. ARANO shows an average PDR of 42.25% for the experimental session being completed. ARANO being compared with RPL shows an average of 39.27% while SPIN performs with lowest of 21.27%. Compared to performance of ARANO, EMARO shows 26.74% and TOPSI with 31.25% of packet delivery ratio. Performance of ARANO is best in packet delivery ratio compared to other schemes, which is acceptable and considered for IoT large scale deployment.

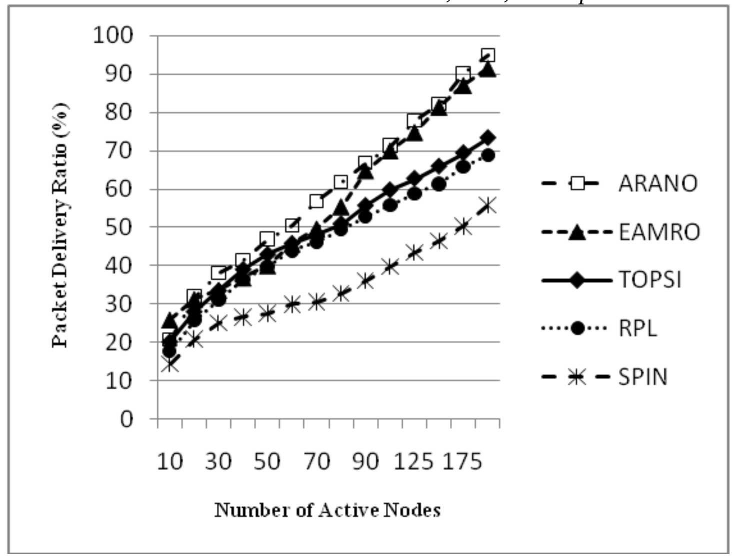

Fig. 7Packet DeliveryRatio Observed for ARANO Route Scheme over IoT

In the hybrid discovery scheme, as Mobile gateways broadcast advertisements within periodic intervals, the overhead slightly increases. However, the overhead is higher in pure proactive scheme compared to the hybrid proactive schemes when the number of registered nodes increases. As the number of registered nodes increases, the Mobile gateway overhead slightly increases. The performance of ARANO is analyzed in terms of percentile of Packet Delivery Ratio, Throughput, and End-to-End delay.

VI. CONCLUSION

This research work proposes on design and implementation of optimal routing protocol for multiple services towards supporting health care and environmental support towards providing effective QoS for streaming data applications, as well as provides an excellent communication interface between mobile nodes on variable IoT node mobility[12]. This work is on health care patient supportive kit which is augmented with location based patient's information thus providing an intuitive way of establishing the communication. The proposed protocol ARANO is a reactive scheme developed for nodes with"limited mobility" deployed under critical conditions. The future work may be towards considering processing requirements at device level and cloud level and also to consider cloud level delays, a major factor which may impact QoS at service levels.

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