Medical & Biological Engineering & Computing (2019) 57:2373–2387
https://doi.org/10.1007/s11517-019-02036-4

ORIGINAL ARTICLE

Design a prototype for automated patient diagnosis in wireless sensor networks

Ayyasamy Ayyanar[1] · Maruthavanan Archana[1] · Y. Harold Robinson[2] · E. Golden Julie[3] · Raghvendra Kumar[4] · Le Hoang Son[5,6]

Received: 27 June 2018 / Accepted: 20 August 2019 / Published online: 29 August 2019

Abstract

It is indeed necessary to design of an elderly support mobile healthcare and monitoring system on wireless sensor network (WSN) for dynamic monitoring. It comes from the need for maintenance of healthcare among patients and elderly people that leads to the demand on change in traditional monitoring approaches among chronic disease patients and alert on acute events. In this paper, we propose a new automated patient diagnosis called automated patient diagnosis (AUPA) using ATmega microcontrollers over environmental sensors. AUPA monitors and aggregates data from patients through network connected over web server and mobile network. The scheme supports variable data management and route establishment. Data transfer is established using adaptive route discovery and management approaches. AUPA supports minimizing packet loss and delay, handling erroneous data, and providing optimized decision-making for healthcare support. The performance of AUPA's QoS approach is tested using a set of health-related sensors which gather the patient's data over variable period of time and send from a source to destination AUPA node. Experimental results show that AUPA outperforms the existing schemes, namely SPIN and LEACH, with minimal signal loss rate and a better neighborhood node selection and link selection. It diminishes the jitter compared to the related algorithms.

Keywords AUPA · QoS · WSN · Route management · Microcontroller · Sensors

1 Introduction

Wireless sensor networks (WSNs) consist of internetworking multiple sensors, which are largely deployed on an open and remotely uncontrolled environment including multitasking capabilities [2]. These sensors lie scattered in an unattended environment (i.e., open field) deployed at remote locations which are situated far from user locations. Design of an elderly support mobile healthcare and monitoring system on WSN for dynamic monitoring of the elderly people was given in [15]. They can be invoked as automatic alarm for handling emergency situations as well as playing role of living assistant [16]. Personal health management was set up to permit health experts to view and update current and log reports of elderly people. The device sets thresholds for sensors and manages experts remotely, which is an essential part for any monitoring model of elderly people [4].

✉ Le Hoang Son
lehoangson2@duytan.edu.vn

Ayyasamy Ayyanar
samy7771@yahoo.co.in

Maruthavanan Archana
archana.aucse@gmail.com

Y. Harold Robinson
yhrobinphd@gmail.com

E. Golden Julie
goldenjuliephd@gmail.com

Raghvendra Kumar
raghvendraagrawal7@gmail.com

1 Department of Computer Science and Engineering, Faculty of Engineering and Technology, Annamalai University, Chidambaram, Tamil Nadu, India

2 Department of Computer Science and Engineering, SCAD College of Engineering and Technology, Tirunelveli, India

3 Department of Computer Science and Engineering, Anna University Regional Campus, Tirunelveli, India

4 LNCT Group of College, Jabalpur, MP, India

5 Institute of Research and Development, Duy Tan University, Da Nang 550000, Vietnam

6 VNU Information Technology Institute, Vietnam National University, Hanoi, Vietnam

In [12], the authors analyzed quality-of-service (QoS) aspects related to implementation of WSN for supporting elderly healthcare and health assistant in patients' health monitoring. Sweetser et al. [7] discuss signal localization algorithm collected from sensor data to monitor patient's health in healthcare clinics. Lewandowski et al. [6] showed a WSN-based implemented healthcare application for analysis of healthcare monitoring systems. The WSN-based designs of sensor networks for applications such as support for health, collect heart activity data, and transmit data over 802.15.4 network nodes were discussed in [1]. Kumar et al. [15] suggested a related device hardware and operational software for a representative system, which supports research aspects towards time synchronization, power management, and chip signal processing. Based on sensory data obtained from clinical and ambulatory settings, the system can support towards understanding the limitations of device as well applications of the WSN technology based upon the in-depth study. Real-time monitoring of health with electrocardiogram (ECG) sensor was investigated in [18]. Lee and Song [13] measured data being transmitted over WSN network which involves remote monitoring and health support. Buratti et al. [19] focused on the design of microsubscription management systems with implementation of dynamic memory kernel over variable payload multiplexing related to service-based events that are the major outcome. It yields good results for e-health applications. Other works of support systems in WSNs can be seen in [3, 8–11, 14, 17, 20, 21, 25–32].

Patient diagnosis system contains the central care units for providing the constant display and understanding the patient's health updates. The patient diagnosis system uses the latest communication technology for the treatment of the patient. This system provides the several measurement methodologies and the signal processing methods. The quality of this type of systems is measured using communication techniques and software technologies.

The objective of this research is to design and develop a health monitoring system that comprises compact body worn devices (embedded on a garment) to monitor and aggregate data from patients, as a network connected over web server and mobile network as shown in Fig. 1. The primary objectives of automated patient diagnosis (AUPA) are as follows:

(i) To survey and analyze the existing approaches to provide consistent QoS aspects over service differentiable WSN networks.
(ii) To support minimizing packet loss and delay using both real-time and simulated approaches.
(iii) Handling erroneous data (aggregated data may have missing values or errors in certain packets). Accuracy of information sent to end user would be better.
(iv) Providing optimized decision-making for healthcare support.

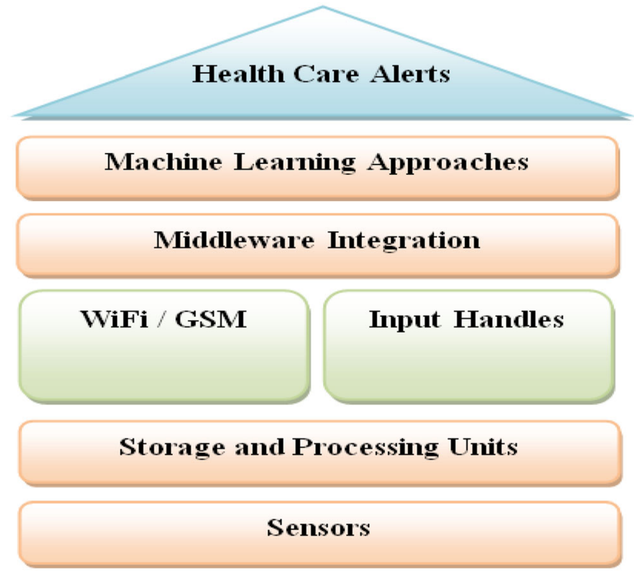


Fig. 1 Stack architecture of AUPA

The importance of creating alerts whenever the abnormal condition happens is addressed in our proposed work. The results suggest the problem of current emergency reply for the patient. The system is designed to reduce the possible critical events and global costs for healthcare systems.

A QoS architectural framework is established for the design of AUPA as healthcare and monitoring kit. It comes from the need for consistent monitoring and maintenance of healthcare among patients and elderly people that leads 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 undetected since it happens only infrequently [22]. Stress on better diagnosis and support on treatment with monitoring are possible through communication systems enabled with WSNs [22]. Such approaches demonstrate better results for monitoring of patients over surgery, rehabilitation scenarios, and daily assessment of life activities among elderly people or people observed as suffering from cognitive disorders like Parkinson's, Alzheimer, or similar diseases.

A case study for healthcare and gathering patient's data is carried out to satisfy the following objectives:

(i) To enable physicians or experts to consistently monitor specific health aspects of patients or elderly members through sensor-based device wearable kit.
(ii) To gather patient's data and develop knowledge repository by employing supervised learning approaches towards disease prediction and suggestive approaches.

(iii) To integrate patient's history and provide support through monitoring with effective diagnosis approaches.

2 Method

2.1 AUPA design

The design factors and challenges of design of AUPA over WSN hold on data depletion, QoS management, robustness over dynamic environment, and highly scalable to numerous sensor devices. Few additional suggestions to the primary challenges are summarized as follows:

(i) Reduction of active traffic load intensity over multiple WSN devices involves data communication minimization over defined wireless channel which includes data aggregation and communication of the network state along with summary of actual data transmitted.
(ii) Maximize the intensity of packet loss along with network life time and support towards achieving adaptive QoS.
(iii) Scalability can be improved by organizing network in a hierarchical clustered approach which utilizes localized interaction among sensor devices over localized algorithms among sensor devices, at the same time robustness to changes in environment. The algorithms can be improved through self-learning and organization, which also includes self-healing and self-adaptive over the configuration setup.

The primary focus of AUPA kit is focused on data maintenance and handling effective decision-making among large networks. AUPA can be defined as a WSN MOTE with the following properties as suggested in Table 1.

Two major supporting functionalities of AUPA are data aggregation [6] and data management factors for variable services along with healthcare-based decision-making. AUPA controls data gathering and analysis through functionality of interrupt handler, where the device collects external environmental parameters using health-supported sensors, process them through processing units, and support data management and decision-making through optimized swarm optimization algorithm such as Ant Colony Optimization (ACO) for analysis.

AUPA adopts the stack architecture structure where each device is equipped with sensory interface setup which can interface multiple sensors such as temperature, EKG, EMG, motion sensors, and body sweat and moisture which are highly sensitive to variable environments as shown in Fig. 2.

Table 1 Properties of AUPA

Program flash memory	32 KB (16 K × 16 K)
Flash memory	32 Kbytes
EPROM	1 KB
SRAM	2 KB
Number of IO	14 slots
Data rate	512 Kbits/s
Frequency of communication	2.4 GHz
Microcontroller size (mm)	58 × 32 × 7
Operating voltage	3.3 to 5 V

AUPA is developed using ATmega 328 microcontroller (see Table 2), which is a simple, cheap, and effective microcontroller for industry-specific applications. It can operate at a low voltage of 5 V for simple applications. It possesses maximum of 14 slots for carrying out multiple services and handles event-specific tasks based on actuations of users. The kit has been developed using C programming which captures multiple sensors or devices for interactivity. WSN nodes are heterogeneous; hence, multiple sensors are built along with the kit to actuate and partake in completing an event as per need of service in use. As ATmega possesses sufficient flash and programming memory, the kit handles large datasets to be stored in external memory and implement monitoring aspects of applications such as habituate monitoring, healthcare monitoring of patient, agricultural farm-specific environment, and pollution control.

AUPA supports inbuilt wireless sensor motes due to its on-board sensor modules, including functionalities such as data logger, and wireless network connectivity for reliable session quality. AUPA works on IEEE 802.15.4 standard, on supportable USB interface through which device can support the data to be gathered. The AUPA equips 16-MHz ATmega 328 microcontroller with 1024-byte EEPROM memory and 64-KB liner programming flash memory as shown in Fig. 3. As optional accessories, AUPA includes sensor for data gathering and transmission including temperature, ECG, EKG, and sweat and moisture sensors as shown in Table 2.

The trans-receiver adopts a data transmission rate of 256 kbps at 2.4 GHz whose transmission range is 50 m within an indoor environment and 100 m in outdoor scenario. The experimentally gathered data have to be temporally stored on the wireless sensor board before being collected and used for decision-making/analysis. AUPA can also be fixed on to 1-MB external flash, which stores the data and buffers the process. The experimental test bed is explained using the organizational setup and test procedures. The healthcare sensors which are used in this project are:

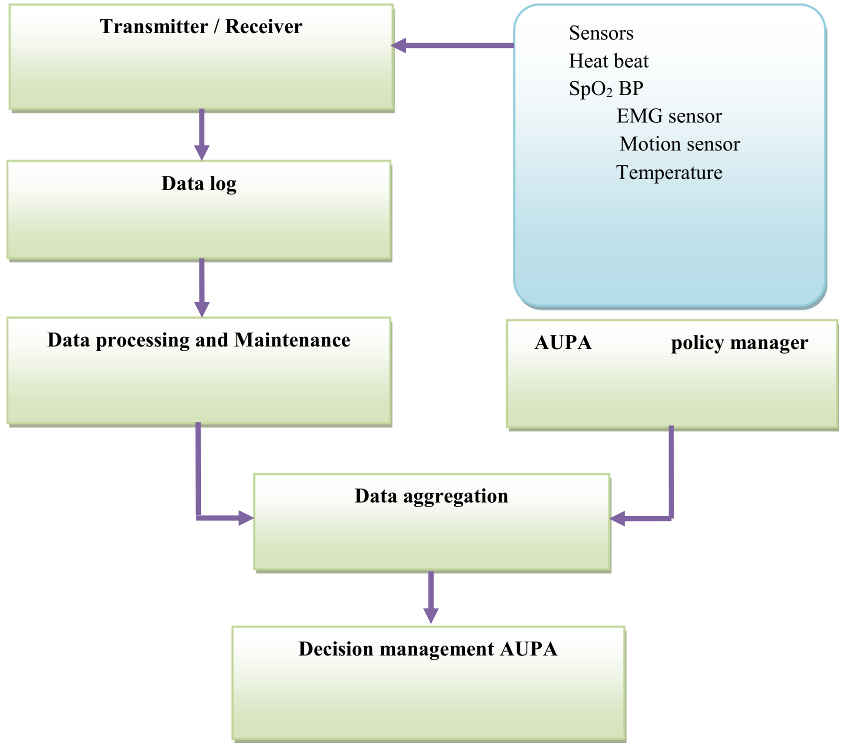


Fig. 2 AUPA functionality model and flow diagram

(i) EMG sensor, which gathers electrical signals produced during contractions of muscle.
(ii) EKG sensor, which collects electrical signals produced by the heart (ECG biosensors).
(iii) Sweat and moisture sensors, to gather the body sweat and moisture level.
(iv) Motion sensor, to gather the abnormal and normal motion of a person.

2.2 Architecture and functionality of AUPA

AUPA mote works on software which manages a fixed array of wireless sensor network nodes fitted with wireless interface backchannel boards allowing data logging and transmission of data over multiple nodes. AUPA mote sensor test bed supports data aggregation and addresses challenges through wireless interconnectivity as interface. The kit supports automated test bed programming and gathers log data generated by experiments into a PC or server as persistent database. The sensor data can be retrieved as source from database, where the database maintains consistent data collected at various iterations including sensor data, time, sensor name, and service adopted from test bed. AUPA is attached with different software components, such as:

(a) Data logger and reading sensor data.
(b) Wireless network interface for communication.
(c) Port/USB interface for collecting the sensor data.

Table 2 AUPA—components

Sensor device name	AUPA
Microcontroller	ATmega 328
Transceiver	IEEE 802.15.4
Data memory	10 KB RAM
External memory	EPROM
Transfer data rate	100–256 Kbps
Communication range	10–25 ft
Model of the channel	Wireless shadowing
Loss component for active path	2.5
Model for collision	Preservative interference

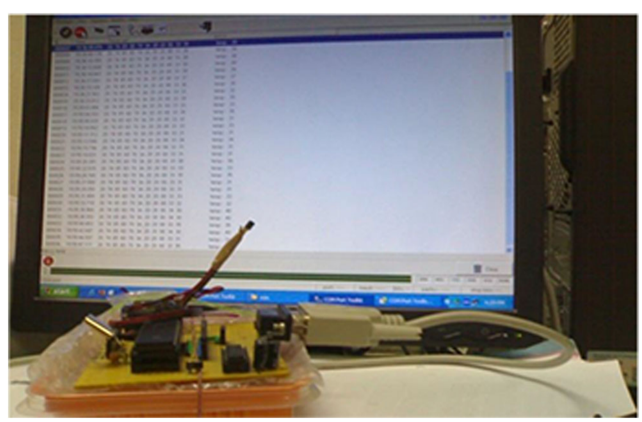


Fig. 3 AUPA designed as healthcare kit with sensors

The architecture is based on a multi-tiered protocol structure, which relies on ZigBee (network and application layers) and 2.4 GHz, IEEE 802.15.4 (physical and data link layers) communication protocol standards, which serves as a network backbone for data transfer and routing phenomenon. To understand and analyze the behavior of WSN network, an application-based test bed is developed with the objectives of implementing, assessing, and validating AUPA architecture. Figure 4 demonstrates the overall design for AUPA which contains the wireless sensor networks, base station, and control unit. The control unit is connected to the Internet, emergency department, and also the mobile user. The Internet can communicate with medical specialists for further updates.

2.3 QoS model architecture

AUPA adopts variable QoS modeling architecture, where multiple WSN nodes are under limited mobility. Any WSN node can act as a source or as destination or as an intermediate node for data transmission. The intermediate forwarding node as A or B … G or H can send or receive the data received from another node as shown in Fig. 5.

AUPA works on multiple sensors such as temperature or humidity or ECG sensors with required buffer to "hold the data" or "transmit the data" to another AUPA node. The experimental test bed is explained using the organizational setup and test procedures. AUPA node referred to as "ni" adopts the following node configuration and route establishment process as shown in Fig. 4. We assume that there are N assorted sensor nodes arranged, which are formed by a connectivity graph of $G = \{V, E\}$, where E represents wireless connections between active nodes. For dissimilar types of active nodes, the broadcasting bandwidth and broadcast control are dissimilar. All connections are unspecified to be directional, and each is connected with a metric representing its connection superiority. To perform sensing responsibilities, there are M active nodes selected from the dynamic sources. All data packets should be launched to the sink node inside the necessary target, where dissimilar types of active nodes contain their individual target constraints. The intention function of the delivery assignments is that all data packets require to be transmitted with the least sum of individual cost. The duration of an active node in the network is defined as the occasion for it to reduce its power. For every Link, Link_{xy} belongs to E and each active route z, we mention Link_{xyz} as,

$$\mathrm{Link}_{xyz} = 1 \text{ if active route } z \text{ includes } \mathrm{Link}_{xy}$$

$$\mathrm{Link}_{xyz} = 0 \text{ if active route } z \text{ does not include } \mathrm{Link}_{xy}$$

$$A_{xy} = \frac{C\text{−Minimum}\left(\mathrm{Link}_x, \mathrm{Link}_y\right)}{\mathrm{Quality}_{xy} \text{ x } \mathrm{Quality}_{yx}} \text{ x } \mathrm{Time}_{xy} \text{ x } t_{xy} \quad (1)$$

2.3.1 Node configuration "ni"

Any node "ni" can be considered to be part of AUPA network, only if the node is accepted using the configuration procedure. An AUPA node is accepted as part of network, only when it is affixed with unique name value and static IP addressing format within its ROM.

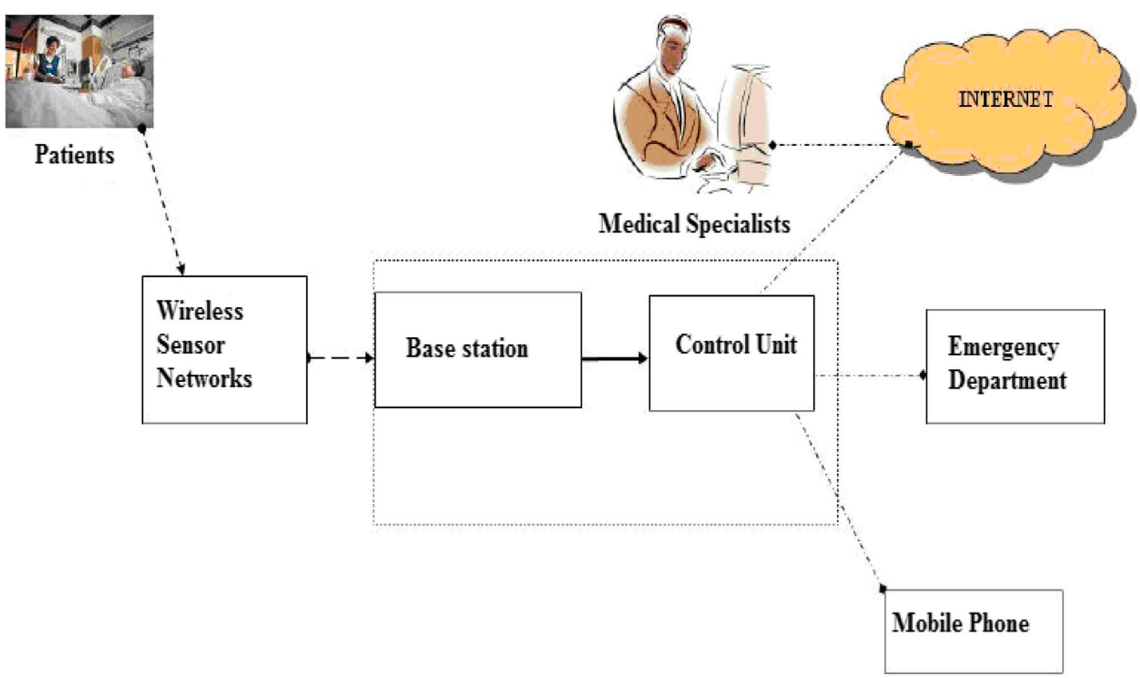


Fig. 4 Overall design for AUPA

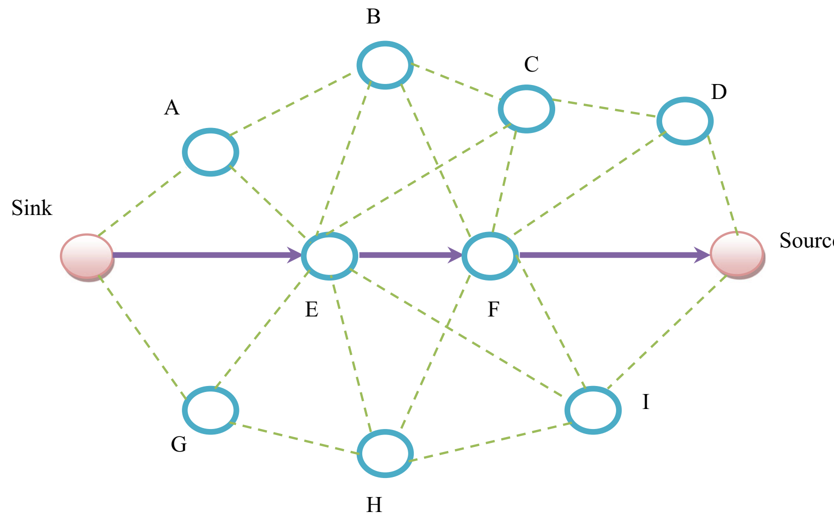


Fig. 5 QoS support with route establishment

2.3.2 Coordinator node

Any set of intermediate nodes can be defined as coordinator node (CN) nodes or coordinator nodes. Figure 4 shows nodes *E* and *F* as coordinator nodes. Nodes which can act as major buffering node can be taken as coordinator nodes. The coordinator nodes link route among intermediate nodes such that multiple source and receiver nodes can communicate. The coordinator nodes maintain variable buffer density such that multiple intermediate nodes do adopt upstream and downstream through coordinator nodes.

2.3.3 Route establishment process

When any AUPA node "ni" receives an instruction or message, it returns an acknowledgement to its sending or upstream node as shown in Algorithm 1.

Algorithm 1: AUPA_Centralized_Algorithm

On receiving this acknowledgement, a node can confirm its route update or link with its neighboring nodes. If the node "ni" does not respond to any instruction or message after many retries, its upstream or sending node will report the node failure to the coordinator node; then AUPA can diagnose the problem with any failure report.

2.3.4 AUPA QoS manager

The QoS manager focuses on providing an adaptive QoS supportive route establishment approach between source and receiver. Allocation of variable buffer among intermediate nodes determines the adaptive path for data transfer. Any intermediate node "ni" can participate in route determination along with coordinator node between the source and receiver node. Multiple sensors gather data and transfer the data between the nodes. The data are stored in intermediate buffer of nodes selected for transfer as explained in Algorithm 2.

Input: **The inventory of routes $AUPA_R$ from AUPA**
Output: **An inventory of generated routes**

Initialize AUPA progress list P_L and applicant list AL = {$AUPA_R$}
while entire amount of process is less than N: do
Perform α-interchange on every active route in AL
if improved route IR is established: then
trace the fractional clarification into $AUPA_R$
else
Perform α -interchange on every active route in AL
end if
end while
Output the best possible solution established so far in $AUPA_R$

Algorithm 2: AUPA_QoS_Manager

Input**: The inventory of routes $AUPA_R$ from AUPA**
Output**: An inventory of generated routes**

1: Set node [i].buffer = NULL
2: If node [i].pkt EQUAL TO node[i].recv THEN Node [i] = NULL
3: For all node [i,j]
4: Select node [i].source = node[j].buffer
5: Select node [i].link (source.node(i),node[j]) = node [i+1] // interfering constraint
Else
6: If node [i].buffer == node [i].NULL then
7: Choose a random node [i-1] of node.recv whose buffer is full
8: Schedule link (node [i],node[j]) respecting interfering constraint
9: node [j].buffer = NULL
10: node [j].buffer = FULL
11: End if
12: End if
13: If node[i].status= "ACTIVE" and node [i].route_status= "TRUE"
then node[i].addroute(route[i])
Else
14: If node[i].status= "INACTIVE"
15: If node[i].route > node [i].congestion_value
node[i].update_route( ) // update the selected route
Else
16: node[i].refresh ( ) // find another new route

The node which participates in route determination updates its status at intermediate intervals of time of experimental runtime. The experimental test bed is explained using the organizational setup and test procedures.

2.3.5 AUPA reversed push path insertion

At the initial stage of reversed push path insertion, for every active node, the calculated path for minimum cost from the

Input: Topology graph TG, the source node set SS, the target set TS, the remaining interval of packets RIP, and the sink node SN
Output: A set of routes with the minimum cost

1: Set candidate list CL = φ and CR= φ
2: Calculate the minimum cost of active path of all source nodes sn_i belongs to SS to the sink using the shortest path algorithm
3: Put every nodes in the source set (SS) into the candidate list (CL)
4: Find the node SS_{new} that has the maximum path cost to the sink from PS, and assign the global variable SS_m = SS_{new}
5: while **CL ≠ φ** do
6: Remove the node SS_{new} from CL
7: Assign the remaining time of packet generated by SS_{new} based on the packet type and DN, and add the value into RIP
8: for all **node SS_m from CL** do
9: Compute the delay incremental $delay_{inc}$ = Delay (SS_{new}, SS_i) + Delay (SS_i, time)
10: Compute the insertion cost as Path_Cost (SS_{new}, SS_i) + Path_Cost (SS_i, time)
11: If the insertion cost is the lowest, and the delay $delay_{inc}$ < RIP_i , pick SS_i as SS_{new}
12: for all **remaining time RIP_i in RIP** do
13: RIP_i = RIP_i - Delay (SS_{new}, SS_i)
14: end for
15: end for
16: if **No candidate SS_{new} is found** then
17: Put the currently found route into AR
18: Start a new route construction procedure
19: Clear RIP
20: end if
21: end while
22: Return AR as the output

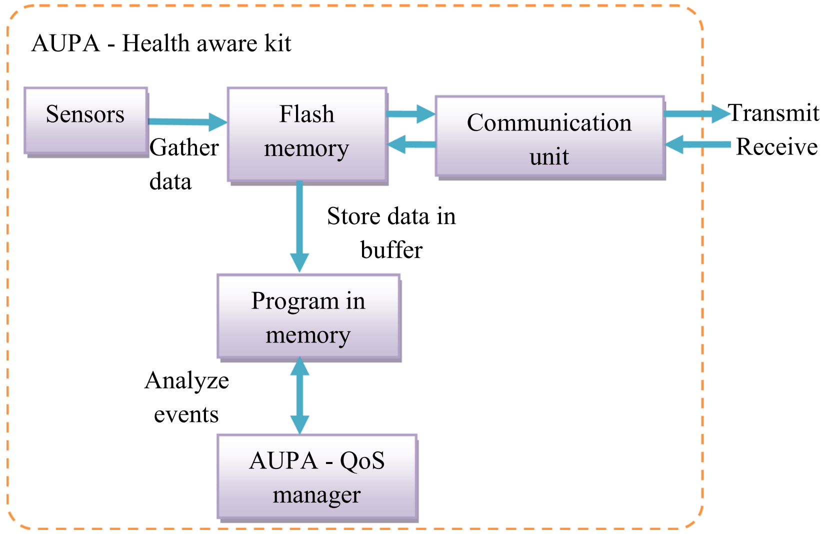


Fig. 6 AUPA test bed setup

beginning node to the sink is established. Reversed push path insertion then discovers the active node that has the prevalent path cost to the sink node and augmentation selection of candidate nodes with the minimum supplementary insertion cost as shown in Algorithm 3.

Algorithm 3: AUPA_Reversed_Push_Path_Insertion

3 Results

The performance of AUPA's QoS approach is tested using a set of health-related sensors which gather the patient's data over variable period of time and send from a source to destination AUPA node. The experimental test bed is prepared as shown in Fig. 5, where the AUPA kit can be deployed on a ZigBee communication kit.

3.1 Test bed preparation

AUPA adopts a step-by-step design process and can be configured over a third-party software tool for autonomous network composition, configuration, and optimization. The AUPA sensor nodes are deployed in a rectangular room measuring 20 ft × 25 ft, where each node is configured over coordinator tools and deployed through gateway [5]. WSN experimental approach of QoS analysis depends upon data logging and data dissemination procedures along with routing program binary as shown in Fig. 6.

Table 3 Test bed generation

Data collection time	10 s
Sensor as nodes	Sp2O2, Temp, humidity
Sensor calibration	+ 1 to − 2%
Power utilization	3 V DC to 9 V
Operating environment	0–30 C
Network layout based on connectivity range	10–15 ft
No. of nodes	5 to 10 nodes
Source, sink in experiment	A, D

3.2 Network programming

Interconnectivity between various AUPA nodes is made feasible using a configuration tool [6] which assigns a name for AUPA node being active. The program image for an AUPA node is written into program memory which gets activated when node is deployed in an experimental process.

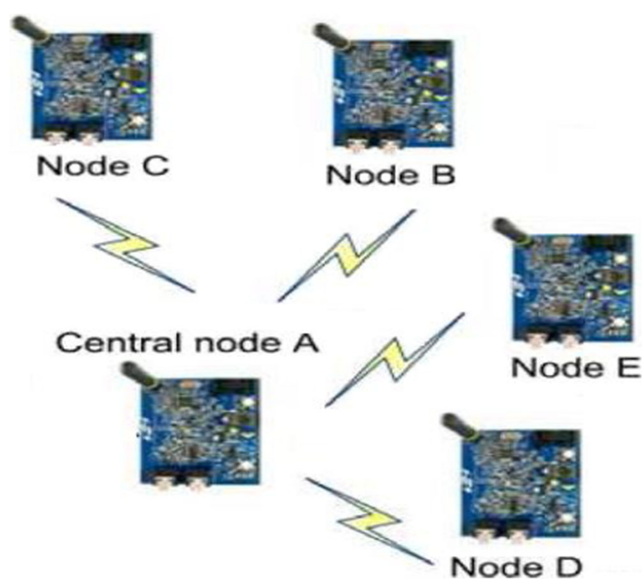
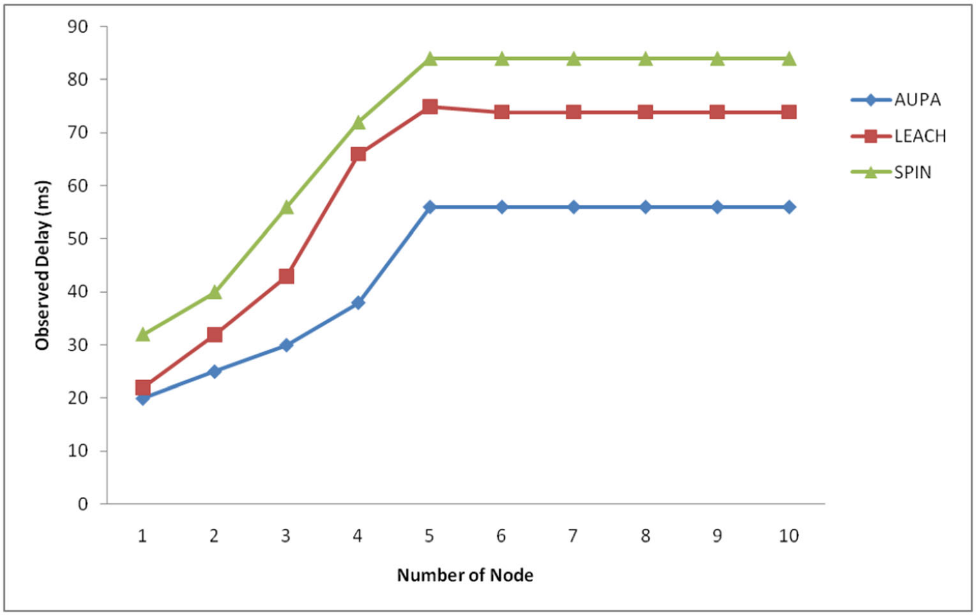


Fig. 7 Indoor test bed implementation

Fig. 8 Observed delay of AUPA



3.3 Data gathering

The experimental data generated during the process in iteration is valuable for understanding the behavior of WSN nodes. The coordinator node also maintains the basic log and operations carried out by node. The log operations maintained also support in understanding the errors [16].

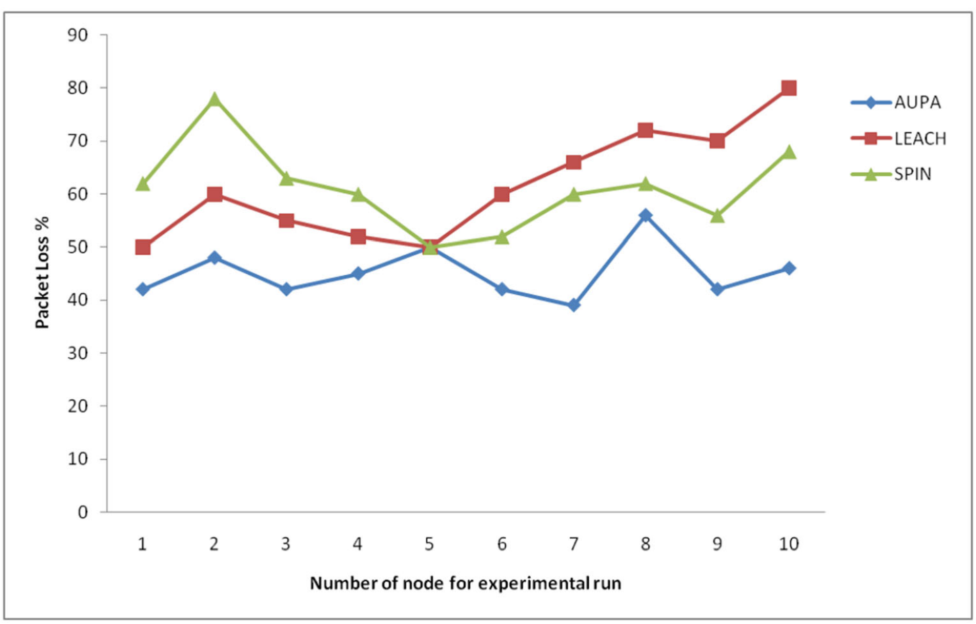
3.4 Accuracy in data collection (Table 3)

The experiment follows (i)–(vi) steps:

(i). Aggregate sensor data
(ii). Store data in variable buffer
(iii). Analyze data on transmission
(iv). Transmit data to another node
(v). Maintain the interval
(vi). Clear the buffer data

The experimental process adopts the steps to collect the data, store, analyze route for proper route selection, and then transmit to another adaptive route based of buffer allocation and data collected. If the transmitted data are not received by intermediate node or co-coordinator node, then re-transmit is requested between sender and receiver node until step (v).

Fig. 9 Measured packet loss over AUPA, LEACH, and SPIN route approaches



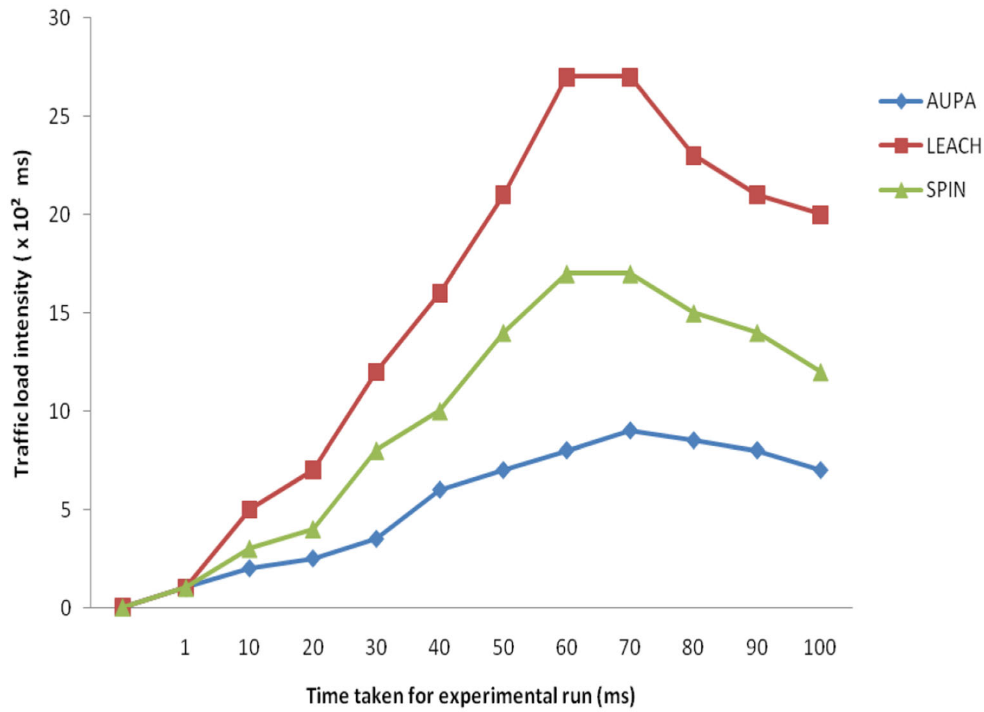


Fig. 10 Traffic load analysis for AUPA approach over data transfer

The signal strength of the received data in the network is called the accuracy. It is based on the network setup, route maintenance, and how the sensor data is aggregated.

3.5 Data aggregation and dissemination

The experiment is carried out based on collected data set size and transmission size. Multiple test iterations are adopted to understand the QoS behavior of AUPA nodes under variable environmental situations of the patient. Patient data are collected from the sender to the receiver, while QoS metrics such as packet loss, end-to-end delay, and other congestion metrics.

3.6 Network deployment and connectivity issues

The AUPA nodes in network are monitored based on signal link capacity while at runtime is analyzed based on the multi-component optimizer system implemented on sensor gateways. The state of the network at runtime can be observed on a device. The internode connectivity establishment time

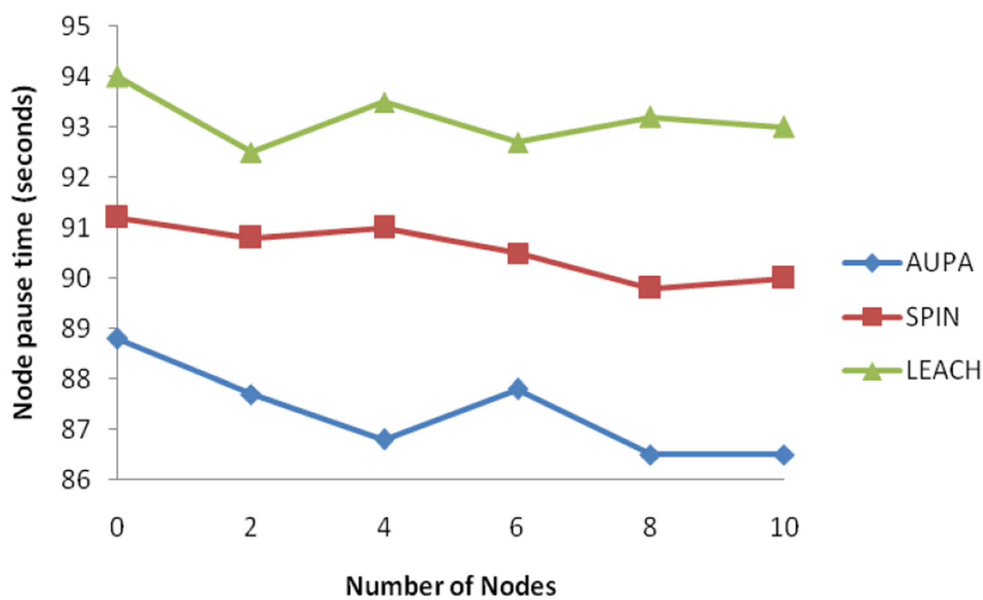


Fig. 11 Reachability over AUPA and existing approaches

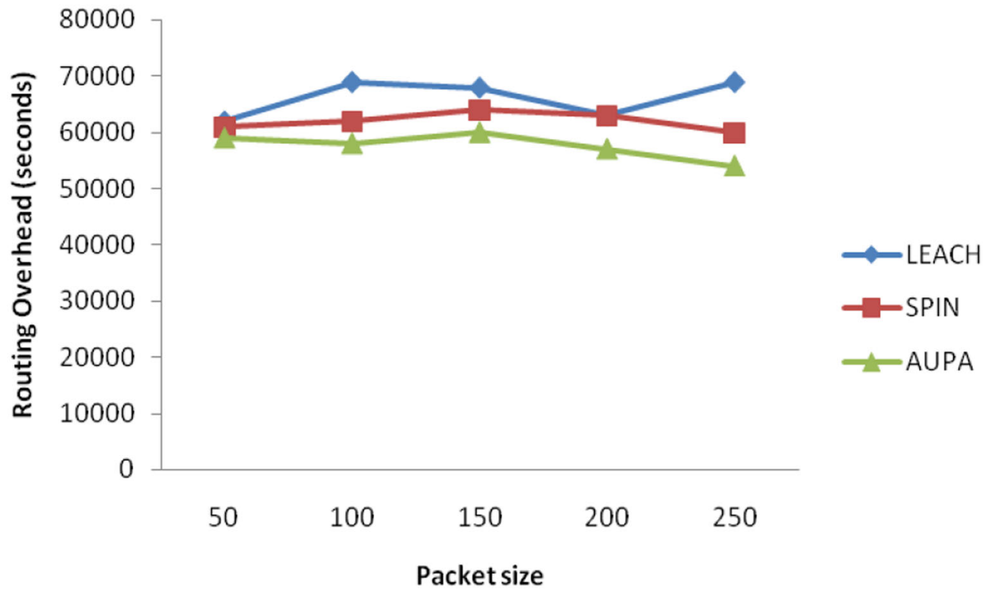


Fig. 12 Packet overhead of AUPA with existing approaches

observed based on packet size, node power consumption, and observed delay for each delivery can be understood from data readings. The deployment strategies followed in solving coverage problem for AUPA are manually assigned initially and then updated at random intervals based on its AUPA node signaling capacity. The possible strategies to be adopted can be force-based, grid-based, or computational geometry procedure-based.

3.7 Indoor setup

AUPA test bed creation to define QoS and efficient route control approach is arranged indoor within a room of 10 × 15 m as shown in Fig. 7. AUPA nodes are placed with an interspacing of 5 to 10 m intermittently. The naming of nodes indicates that node "A" is defined as source node while node "D" as receiver node.

Nodes communicate with each other and possess limited mobility as a patient lying on bed or moving within a room, but not outside the campus or moving into another room. Each node establishes a communication link with the coordinator node which creates the adaptive route for communication. The sensor data transmitted over the network generate traffic over the route created with packet streams whose mean packet size possesses 450 bytes (including TCP/UDP, IP headers). The data transmission generates an approximation of 3500 to 5000 bytes of data traffic over multi-nodal network.

The back-end programming is used to analyze the data which is produced by the sensor nodes and providing the data

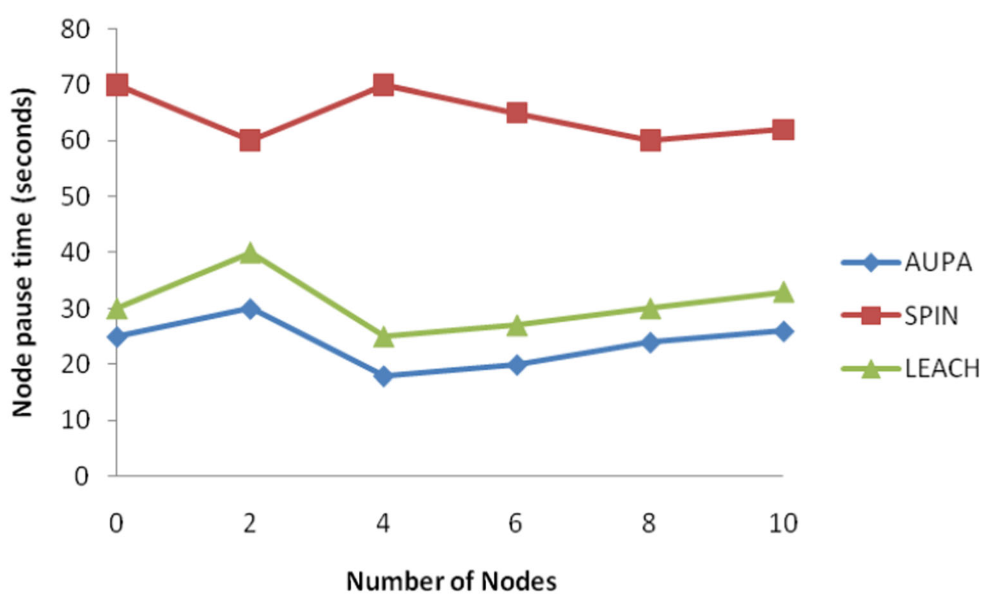


Fig. 13 Latency for AUPA with existing approaches

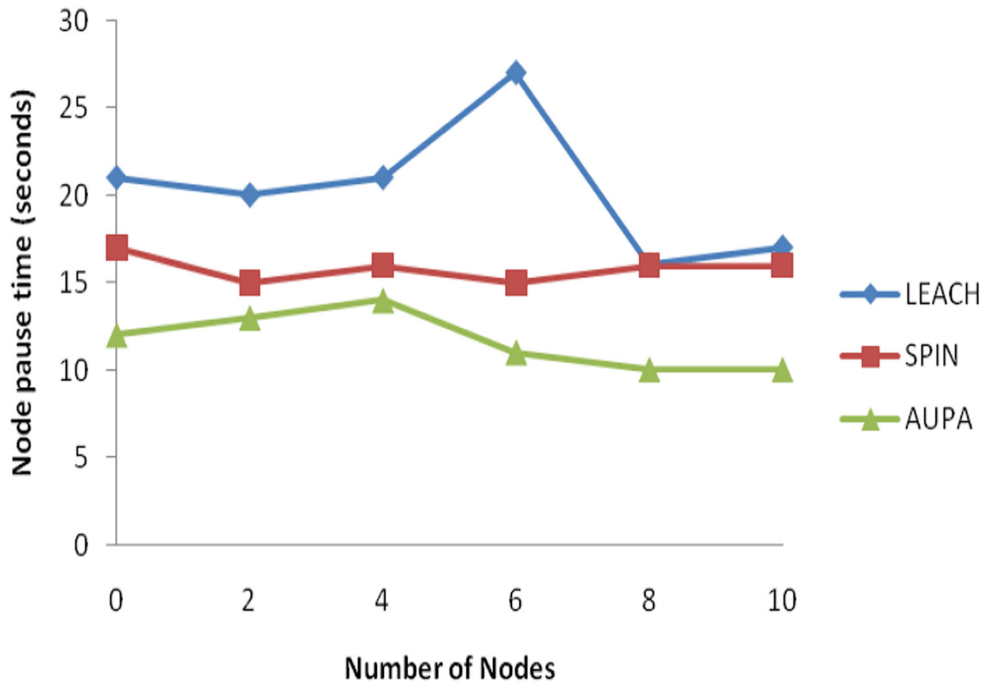


Fig. 14 Jitter for AUPA with existing approaches

communication in the AUPA architecture for implementing the indoor setup.

3.8 Main results (Figs. 8, 9, 10, 11, 12, 13, and 14)

4 Discussion

The performance analysis of AUPA routing scheme is discussed in this section. The experimental test bed uses 10 WSN nodes implemented over limited random mobility speed and conserved over variable real-time data transmitted between WSN nodes. Behavior of AUPA routing approach and its performance is observed over QoS metrics such as throughput, traffic load intensity, observed end-to-end delay, and effective signal connectivity range.

AUPA scheme demonstrates highly reduced signal loss during session in use based on optimal route selection and establishment, where the beacon signal is also considered as a QoS metric. Compared with existing schemes, namely SPIN [23] and LEACH [24], AUPA outperforms with minimal signal loss rate and hence a better neighborhood node selection and link selection is guaranteed. Figure 8 denotes the observed signal rate and loss rate when numerous WSN nodes participate in route establishment and communication. It can be understood from the observed delay rate that AUPA maintains a nearly average minimal delay compared to SPIN and LEACH route schemes, due to adaptive node selection in route establishment. This work does not consider end-to-end delay due to route establishment time due to intermediate node availability.

Figure 9 explains the measured packet loss achieved over 10 WSN nodes possessing AUPA properties. It can be noticed that AUPA showcases an average of 45.62% of packet loss while SPIN shows an average of 64.75% of packet loss. An abnormal behavior is noticed when both SPIN and AUPA show 46% of loss when 5 WSN nodes are used in experiment, which is primarily due to sleep period of WSN node. SPIN shows an abnormal activity, while AUPA demonstrates an expected loss rate.

Figure 10 demonstrates traffic load intensity of three different schemes, namely SPIN, LEACH compared with AUPA. AUPA shows an average of 57.24% of traffic intensity observed over 472 ms of experimental run, compared to 538 ms of LEACH and 594 ms of SPIN routing schemes. AUPA was able to demonstrate a minimal time due to selection of node with better buffer capacity for coordinating in routing process.

Figure 11 explains the readability over WSN nodes possessing AUPA can be identified in linear time. AUPA shows an average of 88.75% of linear time of experimental run compared to existing approaches. The extent to which a node in graph is reachable from others in the proposed work will be used for the quality of service. Figure 12 denotes the observed time it takes to transmit data on a packet-switched network. Figure 12 shows that the AUPA approach of each packet requires extra bytes of format information that is stored in the packet header. It reduces the overall transmission speed of the raw data.

Figure 13 shows that latency is an expression of how much time it takes for a packet of data to get from one designated to another. Figure 14 demonstrates that jitter in the scheme is inversely comparative to bandwidth and as the bandwidth of the scheme enlarges, the jitter also diminishes. The proposed AUPA method diminishes the jitter compared to the related algorithms such as LEACH and SPIN.

To sum up, the proposed AUPA shows better performance than the related methods (SPIN and LEACH) in terms of delay, packet loss, traffic load, reachability, packet overhead, latency, and jitter.

Distributed architecture maintains the data interoperability for the interaction within dissimilar data application. This interoperability will increase system balance and accessibility. AUPA architecture embraces distribution as a significant central process. AUPA architecture is having high-quality application programming interface and product maintenance. Architecture authorizes the reusability and litheness of the product. In addition to that, architecture is most vibrant and application nodes are included at runtime. The architecture drivers are mainly designed for improving the scalability and accessibility. In cloud computing environment, the distributed services are more eminent in near future. Data interoperability is the building of the independent interface at a significant time frame.

AUPA is a distributed architecture design strategy for automated patient diagnosis. AUPA outperforms the existing schemes, namely SPIN and LEACH, with minimal signal loss rate and an enhanced neighborhood node assortment and link selection. It diminishes the jitter compared to the related algorithms.

5 Conclusion

The primary objective of AUPA is to support effective QoS provisioning of WSNs, where providing healthcare for patients who require consistent monitoring and diagnosis. The architecture and implementation provide the design strategy of WSN for healthcare monitoring system based on the following society and environmental aspects.

Social impact This work has a major social impact of supporting the patients in hospital and providing a consistent monitoring of physically disabled people who are in need of support related to medical needs. AUPA kit can help to minimize chances of criticality that arises among patients in case of any emergency. Most of elderly people do not have support for immediate medical care due to hospitals available at remote locations and immediate availability of expert physicians in nearby locations. Hence, such kits do have major social impact among patients and elderly people.

Economic impact The development and maintenance cost of kit is less due to its simplicity. AUPA kit can be easily deployed on the cloth of any human being or can be worn on the wrist such that health data can be collected instantly.

Environmental impact AUPA kit does not impose any environmental hazards as part of its development or working. AUPA does not utilize any hazard gases or release any gases or any other consumable components as part of its working. It does not use any chemical components; hence, it does not have any environmental impact on society or human being. The future work can be extended to machine learning approaches; such intelligent models support disease diagnosis and expert knowledge system.

Authors' contribution All authors have checked and agreed to the submission.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interests.

Ethics This research does not involve any human or animal participation.

References

1. Ayyasamy A, Archana M (2018) Design and analysis of QoS for different routing protocol in mobile ad hoc networks. In Next-generation networks (pp. 247–253). Springer, Singapore
2. Munir A, Gordon-Ross A, Ranka S (2014) Multi-core embedded wireless sensor networks: architecture and applications. IEEE Transactions on Parallel and Distributed Systems 25(6):1553–1562
3. Fasel B, Duc C, Dadashi F, Bardyn F, Savary M, Farine PA, Aminian K (2017) A wrist sensor and algorithm to determine instantaneous walking cadence and speed in daily life walking. Med Biol Eng Comput 55(10):1773–1785
4. Simonsen D, Popovic MB, Spaich EG, Andersen OK (2017) Design and test of a Microsoft Kinect-based system for delivering adaptive visual feedback to stroke patients during training of upper limb movement. Med Biol Eng Comput 55(11):1927–1935
5. Song EY, Lee KB (2010) IEEE 1451.5 standard-based wireless sensor networks. In: Advances in wireless sensors and sensor networks. Springer, Berlin, pp 243–271
6. Lewandowski J, Arochena HE, Naguib RN, Chao KM, Garcia-Perez A (2014) Logic-centered architecture for ubiquitous health monitoring. IEEE journal of biomedical and health informatics 18(5):1525–1532
7. Sweetser D, Sweetser V, Nemeth-Johannes J (2006) A modular approach to IEEE-1451.5 wireless sensor development. In Sensors Applications Symposium, 2006. Proceedings of the 2006 IEEE (pp. 82-87). IEEE
8. Mansor AFM, Ibrahim I, Zainuddin AA, Voiculescu I, Nordin AN (2017) Modeling and development of screen-printed impedance biosensor for cytotoxicity studies of lung carcinoma cells. Medical & biological engineering & computing, 1-9

9. Leuenberger K, Gonzenbach R, Wachter S, Luft A, Gassert R (2017) A method to qualitatively assess arm use in stroke survivors in the home environment. Med Biol Eng Comput 55(1):141–150
10. Yu R, Mak TW, Zhang R, Wong SH, Zheng Y, Lau JY, Poon CC (2017) Smart healthcare: cloud-enabled body sensor networks. In Wearable and Implantable Body Sensor Networks (BSN), 2017 IEEE 14th International Conference on (pp. 99-102). IEEE
11. Gravina R, Alinia P, Ghasemzadeh H, Fortino G (2017) Multi-sensor fusion in body sensor networks: state-of-the-art and research challenges. Information Fusion 35:68–80
12. Verdone R, Dardari D, Mazzini G, Conti A (2010) Wireless sensor and actuator networks: technologies, analysis and design. Academic Press
13. Lee KB, Song EY (2005) Object-oriented application framework for IEEE 1451.1 standard. IEEE Trans Instrum Meas 54(4):1527–1533
14. Lee C, Murata S, Ishigaki K, Date S (2017) A data analytics pipeline for smart healthcare applications. In: Sustained simulation performance 2017. Springer, Cham, pp 181–192
15. Kumar P, Lee YD, Lee H (2010) Secure health monitoring using medical wireless sensor networks. In Networked Computing and Advanced Information Management (NCM), 2010 Sixth International Conference on (pp. 491-494). IEEE
16. Patil N, Mulla A, Nikam P, Shinde D (2013) Medical application based on wireless sensor network. International Journal of Computer Science and Communication Engineering 2(2):43–46
17. Al Mamun KA, Alhussein M, Sailunaz K, Islam MS (2017) Cloud based framework for Parkinson's disease diagnosis and monitoring system for remote healthcare applications. Futur Gener Comput Syst 66:36–47
18. Zhang Z, Wang H, Vasilakos AV, Fang H (2012) ECG-cryptography and authentication in body area networks. IEEE Trans Inf Technol Biomed 16(6):1070–1078
19. Buratti C, Verdone R, Ferrari G (2011) Sensor networks with IEEE 802.15. 4 systems: distributed processing, MAC, and connectivity. Springer Science & Business Media
20. Ngan TT, Tuan TM, Son LH, Minh NH, Dey N (2016) Decision making based on fuzzy aggregation operators for medical diagnosis from dental X-ray images. J Med Syst 40(12):280
21. Tuan TM, Fujita H, Dey N, Ashour AS, Ngoc VTN, Chu DT (2018) Dental diagnosis from X-ray images: an expert system based on fuzzy computing. Biomedical Signal Processing and Control 39: 64–73
22. Da Xu L, He W, Li S (2014) Internet of things in industries: a survey. IEEE Transactions on industrial informatics 10(4):2233–2243
23. Perrig A, Szewczyk R, Tygar JD, Wen V, Culler DE (2002) SPINS: security protocols for sensor networks. Wirel Netw 8(5):521–534
24. Al-Baz A, El-Sayed A (2018) A new algorithm for cluster head selection in LEACH protocol for wireless sensor networks. Int J Commun Syst, 31(1)
25. Harold Robinson Y, Golden Julie E, Saravanan K, Kumar R, Son LH (2019) FD-AOMDV: fault-tolerant disjoint ad-hoc on-demand multipath distance vector routing algorithm in mobile ad-hoc networks. J Ambient Intell Humaniz Comput. https://doi.org/10.1007/s12652-018-1126-3
26. Kapoor R, Gupta R, Son LH, Jha S, Kumar R (2019) Adaptive technique with cross correlation for lowering signal-to-noise ratio wall in sensor networks. Wirel Pers Commun 105(3):787–802
27. Santhana Krishnan R, Golden Julie E, Harold Robinson Y, Son LH, Kumar R, Abdel-Basset M, Thong PH (2019) A new algorithm for high power node multicasting in wireless sensor networks. IEEE Access 7:38584–38592
28. Harold Robinson Y, Golden Julie E, Kumar R, Son LH (2019) Probability-based cluster head selection and fuzzy multipath routing for prolonging lifetime of wireless sensor networks. Peer-to-Peer Networking and Applications. https://doi.org/10.1007/s12083-019-00758-8
29. Khan T, Singh K, Son LH, Abdel-Basset M, Long HV, Singh SP, Manjul M (2019) A novel and comprehensive trust estimation clustering based approach for large scale wireless sensor networks. IEEE Access 7:58221–58240
30. Harold Robinson Y, Santhana Krishnan R, Golden Julie E, Kumar R, Son LH, Thong PH (2019) Neighbor knowledge-based rebroadcast algorithm for minimizing the routing overhead in mobile ad-hoc networks. Ad Hoc Netw 93:101896–101909
31. Balaji S, Julie EG, Robinson YH, Kumar R, Thong PH, Son LH (2019) Design of a security-aware routing scheme in mobile ad-hoc network using repeated game model. Computer Standards & Interfaces 66:103358–103368
32. Brezulianu A, Geman O, Zbancioc MD, Hagan M, Cristian A, Jude Hemanth D, Son LH (2019) Heart activity monitoring using inductive sensors. Sensors 19(15):3284–3300

A. Ayyasamy is born and brought up from Malaipatti, Sankarankoil, Tamil Nadu state of India. He completed his B.E. and M.E. in Computer Science and Engineering from Annamalai University, Chidambaram, Tamil Nadu, India, in the years 2006 and 2008 respectively. He is working as Assistant Professor in Department of Computer Science and Engineering, Faculty of Engineering and Technology, Annamalai University, from 2007 where he obtained his Doctorate in 2015. He has guided 20 undergraduate students and 18 postgraduate students. He has the credit of publishing nearly 19 research articles in the referred and peer-reviewed international journals/conferences and presented nearly 8 papers in the national conferences. His areas of interest are mobile ad hoc network, wireless network, video streaming services, streaming media architectures, QoS and routing protocol, and computer engineering as well as network security. He is also serving as editor-in-chief of International Journal of Networking (BioInfo publications). He is also serving as an editorial board member for various international journals and reviewer in IEEE, Springer, Ad Hoc and Sensor Wireless Networks (AHSWN), etc. He also accepted an invitation to be a technical review committee member for many international conferences (India, USA, London, Malaysia, etc.). He is a professional member of ACM journals (member ID: 9839431), International Association of Engineering, and senior member in Universal Association of Computer and Electronics Engineers. He received Young Faculty award from Center for Advanced Research and Design in 2015.

M. Archana is an Assistant Professor in Information Technology, Department of Computer Science and Engineering at Annamalai University since 2008. She received her B.E. degree in Information Technology with gold medal and stood one among the gold medalist of Annamalai University in 2007. She received her M.E. (Distinction) degree in Computer Science and Engineering from Annamalai University in the year 2011. She completed her Ph.D. in 2016. Her areas of interest are image and video processing, broadcast tennis video, pattern classification, and wireless network. She has the credit of publishing nearly 9 research articles in the referred and peer-reviewed international journals and presented nearly 2 papers in the national conferences. She is a member of International Association of Engineering.

Y. Harold Robinson is currently working as an Associate Professor and Head, Department of CSE in SCAD College of Engineering and Technology, Tirunelveli. He finished his M.E. degree in Anna University, Chennai. He completed Ph.D. in Anna University Chennai. His research interests are wireless networks mobile computing and wireless sensor networks. He has published several research papers in international journals. He has presented many papers in national and international conferences in network security, mobile computing, and cloud computing.

E. Golden Julie received her B.E. degree in Computer Science and Engineering in 2005 from Anna University Chennai and M.E. degree in Computer Science and Engineering in 2008 from Anna University Chennai. She completed her Ph.D. in 2017 from Anna University Chennai. Presently, she is working as assistant professor in Regional Centre Anna University, Tirunelveli, India. She has published many research papers in various fields. Her research area includes wireless sensor ad hoc networks and image processing.

Raghvendra Kumar is working as Assistant Professor in Computer Science and Engineering Department at L.N.C.T Group of College Jabalpur, MP, India. He received B. Tech. in Computer Science and Engineering from SRM University Chennai (Tamil Nadu), India, M. Tech. in Computer Science and Engineering from KIIT University, Bhubaneswar, (Odisha) India, and Ph.D. in Computer Science and Engineering from Jodhpur National University, Jodhpur (Rajasthan), India. He has published 86 research papers in international/national journal and conferences including IEEE, Springer, and ACM as well as serve as session chair, co-chair, and technical program committee members in many international and national conferences and serve as guest editors in many special issues from reputed journals (indexed by: Scopus, ESCI). He also received best paper award in IEEE Conference 2013 and Young Achiever Award-2016 by IEAE Association for his research work in the field of distributed database. His research areas are computer networks, data mining, cloud computing and secure multiparty computations, theory of computer science, and design of algorithms. He authored 12 computer science books in field of data mining, robotics, graph theory, and turing machine by IGI Global Publication, USA, IOS Press Netherland, Lambert Publication, Scholar Press, Kataria Publication, Narosa, Edupedia Publication, S. Chand Publication, and Laxmi Publication.

Le Hoang Son obtained the PhD degree on Mathematics – Informatics at VNU University of Science, Vietnam National University (VNU) in conjunction with the Politecnico di Milano University, Italy in 2013. He has been promoted to Associate Professor in Information Technology in Vietnam since 2017. Dr. Son worked as senior researcher and Vice Director at the Center for High Performance Computing, VNU University of Science, Vietnam National University during 2007 - 2018. From August 2018, he is Senior Researcher of Department of Multimedia and Virtual Reality, VNU Information Technology Institute. His major fields include Artificial Intelligence, Data Mining, Soft Computing, Fuzzy Computing, Fuzzy Recommender Systems, Geographic Information System. Dr. Son is an Associate Editor of Journal of Intelligent & Fuzzy Systems (SCIE), IEEE Access (SCIE), Data Technologies and Applications (SCIE), International Journal of Data Warehousing and Mining (SCIE), Neutrosophic Sets and Systems (ESCI), Vietnam Research and Development on Information and Communication Technology, VNU Journal of Science: Computer Science and Communication Engineering, Frontiers in Artificial Intelligence. He serves as Editorial Board of Applied Soft Computing (SCIE), PLOS ONE (SCIE), International Journal of Web and Grid Services (SCIE), International Journal of Ambient Computing and Intelligence (ESCI), and Vietnam Journal of Computer Science and Cybernetics.