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Fuzzy Query Processing in Wireless Senor Networks for Animal Health Monitoring

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Abstract: **In Wireless Sensor Network (WSN), Fuzzy query processing approach provides common natural language speci- fication of the desired data , eliminating the usage of numerical threshold values as predicates. The fuzzy query results are asso- ciated with a degree of membership measurement that indicates how closely each returned data value matches the semantic intent of the fuzzy query, providing applications with additional information that can be used to reason about the query result. Fuzzy queries are applicable for applications that demands single query that can compute values for spatial objects with different threshold values thus reducing message transmission at the sensor network and the post-hoc analysis at the external server. The proposed system can handle different types of fuzzy queries for different scenarios for animal monitoring application. Efficient query processing depends on the routing algorithm used. This work utilizes Minimum Bounding Rectangle (MBR) based routing with static nodes as cluster head and mobile nodes as cluster member to efficiently and reliably disseminate query and retrieve the query results.**

Keywords: **Wireless Sensor Network (WSN), Base Station (BS), Cluster Head(CH), Moving Sensor(MS), Fuzzy Logic System(FLS), Membership Function(MF).**

I. INTRODUCTION

In WSN, we can sense the objects by querying the sensor nodes. The results for the query is obtained when the sensed values of the sensor node matches the predicates in the query. Existing query processing approaches retrieve the sensed data values from the sensor by considering exact threshold values (eg : temperatureValue >40) specified by the user. This kind of querying mechanism can miss the values that are closer to the specified threshold values. To overcome this issue, we propose to use fuzzy queries which can retrieve and rank the query result based on how well the data relates to the semantics of the query. Each sensed data values on sensor is associated with a linguistic term and the corresponding membership function indicates the degree of closeness of the data value to a particular linguistic term. The sensors communicate with each other or to an external base-station (BS) by means of any routing mechanism. We propose a heterogeneous routing strategy to route queries between both static and dynamic sensors. Ground Based Sensors (Static Sensors) are deployed over the wide geographical area which is divided into many rectangular grids. Each grid has a single static node called cluster head. It acts as an intermediate to relay the query results between the Mobile Sensors (Dynamic Sensors) and the Sink node.

In this paper, we propose a fuzzy query processing mech- anism for processing fuzzy queries to learn the health con- dition of animals based on their body temperature values in Animal Health Monitoring Application. Finally, we compare the performance of proposed system with the traditional query processing system for this application. The paper is organized in the following manner: Section II tells about Existing Meth- ods, Section III explains the proposed system, Section IV and Section V deals with the performance analysis and conclusion respectively.

II. EXISTING METHOD

Many researchers have been carried out in the area of fuzzy processing for WSN under different context. A Fuzzy Logic System [1] is used to analyse and estimate the network lifetime for Wireless Sensor Network. To perform this, a type-2 fuzzy membership function called Gaussian MF with uncertain standard deviation is used to model a single node lifetime of sensor node. A Fuzzy processing approach called Mamdami’s Fuzzy Logic model [2] has been employed for route selection during packet transfer in the network. In this approach, an individual trust of a node is calculated with respect to other nodes by considering the various parameters such as Data Packet Forwarding, Control packet forwarding and Data packet precision. These metric values are then given as an input to the Fuzzy Logic System and the fuzzy value is obtained as an output from the inference engine which computes the best trust route.

Mamdani and Sugeno Fuzzy Inference Systems [3] is capable of localizing a sensor node given the positions of its neighbour nodes. It uses a range free enhanced weighted cen- troid localization method using edge weights of adjacent nodes to localize a sensor node. To achieve this, the anchor nodes (first adjacent nodes) are found out and their edge weights based on RSSI is computed using Mamdani and Sugeno fuzzy inference systems for localization. A Fuzzy Expert System based strategy is used for Cluster Head Selection [4] that took into account battery life, distance from the base station and the sum of distance between the selected node and the other nodes. The probability of a node being elected as cluster head is defined using various linguistic variable such as T (chance) =

{verysmall, small, medium, littlelarge, large, verylarge}.

Many sensor based applications uses query based data accessing methods where user poses queries to retrieve databased on certain criteria. In such classical queries, the sensor nodes retrieves value only when they meet the exact threshold, the data values that are too close to the condition can be missed out. For example, for the query ”Select temperature from sensors where temperature > 40”, the temperature value that is exactly > 40 alone is retrieved, though the sensor readings 39.45 or 39.95 is close to the specified value. There- fore to retrieve these values, the programmer has to change the threshold value repeatedly, until the desired results are returned. Also, to obtain data values that shows the closeness to the threshold value, in traditional query processing approach post-hoc analysis should be carried out. But, Fuzzy query processing system eliminates these issues and it is capable of retrieving and ranking the query results based on the degree of closeness.

The proposed fuzzy query processing system for animal monitoring is an extension to fuzzy query processing system proposed by Doman et al [5] for heterogeneous environment where static and dynamic nodes are involved. Additionally it handles various types of fuzzy queries such as spatial monitoring queries, temporal monitoring queries, aggregation queries and ID based queries.

III. SYSTEM ARCHITECTURE

The user formulates the fuzzy query which is transmitted into the sensor network via the sink node. Deployment of the system is described below. The sink node broadcast the queries to the required spatial region using a spatial aware routing scheme. The mobile sensor nodes (animals carrying sensors) present in the region of interest of the query, respond to the query to the sink through the cluster head in the region.

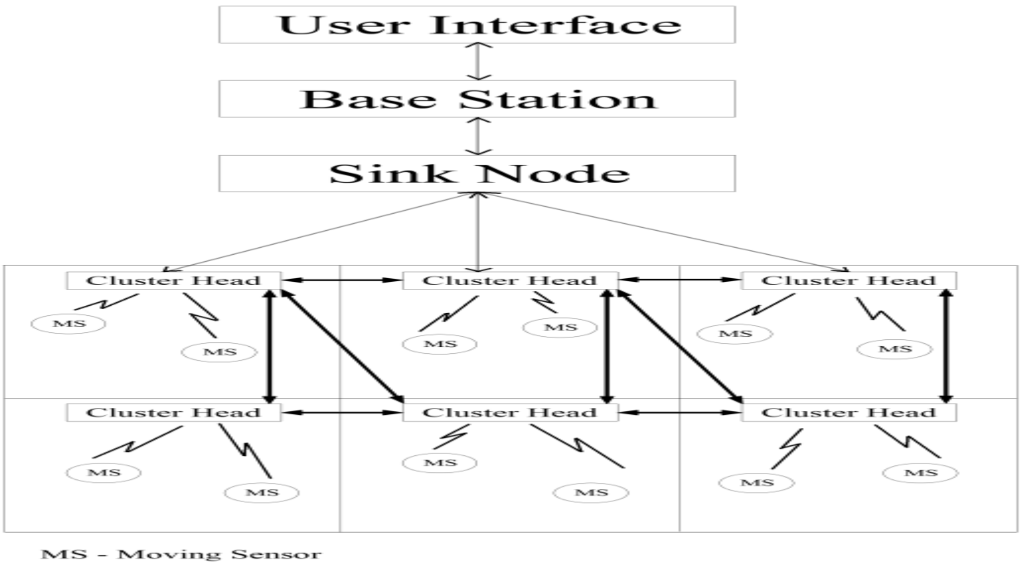

Fig. 1: System Architecture

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The various functional modules of the proposed system is shown in Fig.2

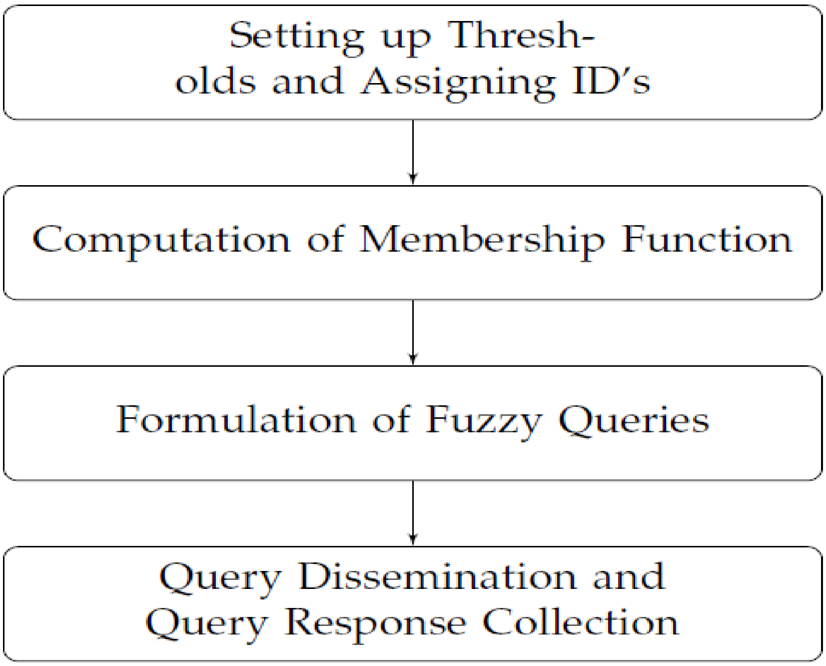

Fig. 2: System Flow Diagram

A. Setting up of threshold's and assigning Id's

Animals are categorised or divided based on their species. Each species are assigned an unique id. Diseased animals can be identified based on the following factors such as appear- ance of animal, Movement, Eyes, Ears, Nose and Muzzle, Mouth and body temperature change. In animals, the body can only work properly at certain temperature. The animal body maintains itself at a constant temperature, within a small range, in order for the systems to work properly. A change in the temperature of the body is a sign of ill health. The temperature values are initialised for each species in the sensors. The normal body temperature is different in different types of animals. In our proposed work the body temperature is taken for monitoring the animals rather than its appearance. Hence sensors are attached to the animal body to sense the body temperature and also to answer the fuzzy query send by the base station. Sensors are initialized with a normal body temperature[10] of the animal to which it is attached that serve as a reference value and help to check the health of the animal by comparing the threshold with its current value.

TABLE I. ANIMAL BODY TEMPERATURE

S.No	Animal	Temperature
1	Buffalo	38.2 - 43.7
2	Sheep	39.0 - 45.0
3	Llama, alpaca	38.0 - 43.5
4	Donkey	38.2 - 44.0
5	Chicken	42.0 - 48.0
6	Calf	39.5 - 45.0
7	Goat	39.5 - 46.0
8	Camel	34.5 - 41.0
9	Horse	38.0 - 44.0
10	Pig	39.0 - 46.2

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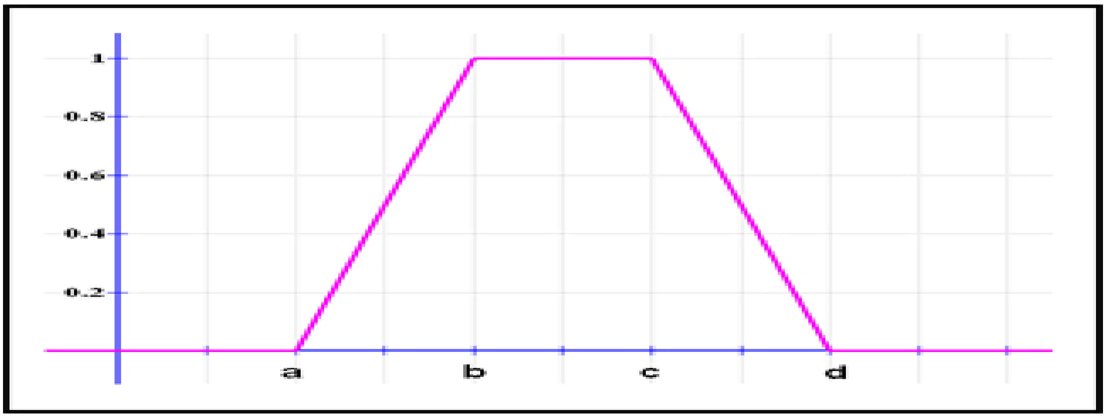
B. Computation of Membership Function

This computes the membership functions for the fuzzy query system. Temperature is chosen as a linguistic variable for the system. Linguistic variables are the input or output variables of the system whose values are words or sentences from a natural language, instead of numerical values. For linguistic variable linguistic terms are defined. For example, T(t) = f(Normal ,critical, highly critical) can be a set of decompositions for the linguistic variable temperature. Each member of this decomposition is called a linguistic term and can cover a portion of the overall values of the temperature. Then, the degree of membership is computed for the linguistic variable to quantify the linguistic term. Some of the member- ship functions that can be used to quantify the linguistic terms are [8] triangular MF, trapezoidal MF, L-shaped MF and S-shaped MF. In triangular MF a single point is defined with a degree of membership as 1, in trapezoidal MF a range of values is defined with a degree of membership as 1, S shaped MF provides a non-linear progression of membership grade and L shaped MF provides a linear progression of membership grades. But both S and L shaped MF's has the degree of membership as 1 after it reaches constant value. Since the proposed system uses range of values to define its membership function, trapezoidal MF is used . Trapezoidal membership function is defined by a lower limit a, an upper limit d, a lower support limit b, and an upper support limit c, where a< b< c< d.

$$\mu_A X = \begin{cases} 0 & (x < a) or (x > d) \\ (x-a)/(b-a) & a \le x \le b \\ 1 & b \le x \le c \\ (d-c)/(d-x) & c \le x \le d \end{cases}$$



C. Formulation of Fuzzy Queries

Construction of appropriate queries to retrieve the health status of the animals is of prime importance to retrieve the required data in an energy-efficient manner. The goal of fuzzy query processing is with minimal queries the maximum infor- mation is obtained, thus saving the energy of the sensor nodes by reducing the message transmission. The proposed system uses different types of fuzzy queries used for monitoring the health condition of the animals to obtain the information effectively.

1) Spatial Monitoring Queries: It retrieves the health con- dition of the animals over a given spatial range.

Example:

SELECT COUNT nodeid, location, temperature

FROM Sensor WHERE temperature > Highly Critical

AND location IN LocationRange[l1, l2]

2) Temporal Monitoring Queries: It retrieves the health condition of the animals over a given spatial range.It retrieves the status of the various health indicating parameters of the animals at a time instant or over a time period.

Example:

SELECT COUNT nodeid, location, temperature

FROM Sensor WHERE temperature > Highly Critical

AND location IN TimeInterval[t1, t2]

3) Aggregation Queries: It retrieves collective information about the health conditions of the animals

Example:

SELECT COUNT nodeid, location, temperature

FROM Sensor WHERE temperature > Highly Critical

4) ID based Queries: It accesses the health information of the animals using their ID's

Example:

SELECT COUNT nodeid, location, temperature

FROM Sensor WHERE temperature > Highly Critical

AND nodeid = 'C'

D. Query Disemmination and Query Response Collection

1) Deployment Phase: The system employs heterogeneoussensor nodes such as static and mobile sensors. The whole field is divided into several rectangular regions called minimum bound rectangles(MBR). It is the rectangle with smallest measure in area, volume or in higher dimensions within which all the points lie. It is commonly used to indicate the position of a feature in spatial query or spatial indexing purposes and used to compute within which MBR an individual spatial object is associated with. Each rectangular region is assigned with a static sensor node that acts as a cluster head for the mobile sensors that join dynamically.

2) Neighbours Discovery Phase: After the deployment the sink node sends a Hello message to its transmission range. The CH which receives the Hello message will respond to the sink with ACK message. Thus the sink node gains the knowledge of its neighbouring node to transmit queries later. Additionally all the CH which receives the Hello message will perform flooding thus the message is disseminated to entire network. Each CH will receive multiple copy of the same Hello message from its neighbours which serve as a neighbour discovery message. The neighbours Ids can be retrieved and stored it in a local routing table from the message and the message is discarded without further forwarding.

Neighbor Discovery Algorithm

1) SINK broadcast"Hello Message" to its transmission range

2) CH within the transmission range of SINK reply using ACK message to SINK

3) SINK stores the CH ID's retrieved from the ACK message of CH in its buffer

4) Each CH broadcast Hello messages to know its neighbour CH

5) Each CH stores the neighbour CH IDs in its buffer from the IDs extracted from Hello message

3) Query transmission and Reception Phase: Mobile Sen- sors (MS) are the sensors that are attached to the collar of each animals. It is assumed that each mobile sensors are capable of knowing its location using GPS or any localization techniques. The mobile sensors will update its current CH information by sending CH discovery message periodically and getting the response from the CH. This process benefits mutually the CH and the mobile sensor node to whom the message has to be communicated. As long as the MS is within the MBR of CH, it can receive the query from the CH and can respond to the query. In case of location based fuzzy query, the CH verifies whether its MBR overlaps the querys space. If it overlaps, it will retain the query for execution and also forward the query to its neighbours whose query space also overlaps. But if the query space does not overlap, it will forward to the neighbour's to which the query space overlaps or otherwise it will drop the query. The query results are collected by the CH and transmitted to the sink through their nearest uplink parent.

Query Transmission and Reception Algorithm

1) MS send"CH discovery message" to CH along with

MS information

2) CH reply MS along with CH information

3) CH sends the fuzzy query to its MS

4) As long as MS is within the MBR of CH it will respond

5) Query results collected by CH transmitted to sink

IV. PERFORMANCE EVALUATION

The proposed approach was simulated in Omnet++ tool. We assume that all nodes have different transmission ranges and different energy levels. Sensor nodes know its location as well as it neighbours location by neighbour discovery phase and CH discovery phase.

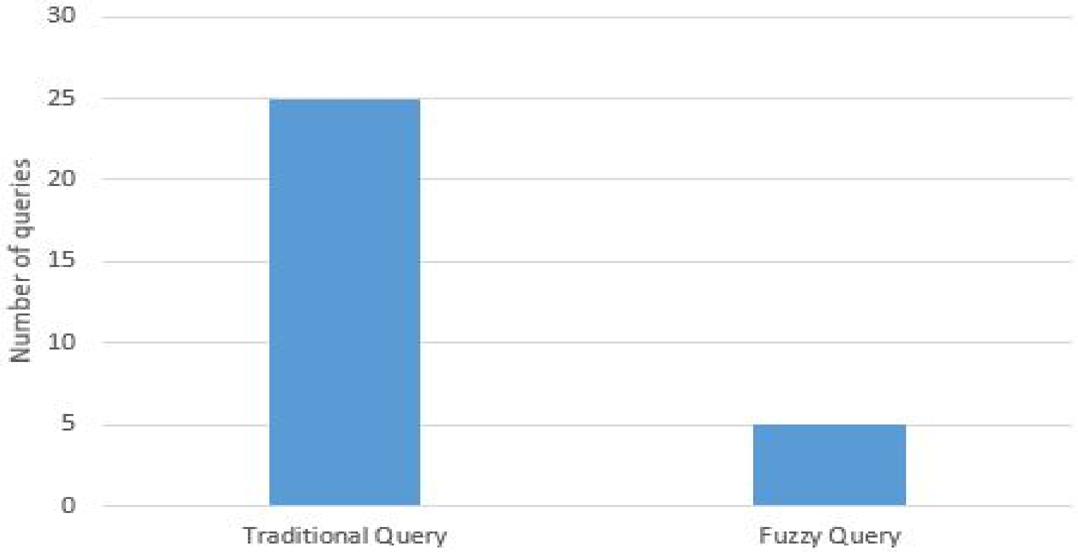


Fig. 4: Query Transmission from Sink to CH

Figure 4 and Figure 5 shows the query overhead of the proposed fuzzy query processing system with the traditional query processing system. It shows that the fuzzy query system uses 80 percentage less queries compared to the traditional system. This is due to the usage of linguistic terms in fuzzy

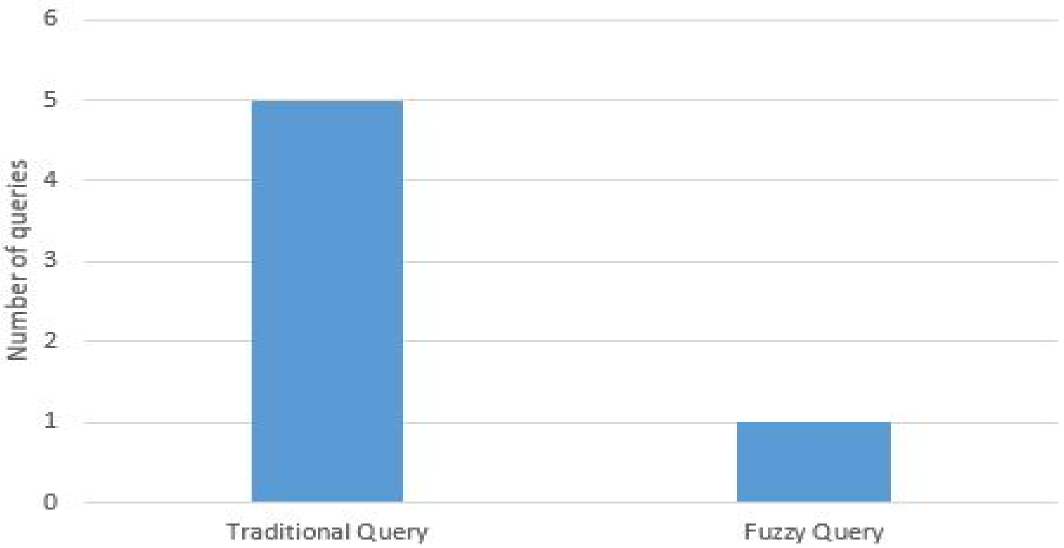


Fig. 5: Query Transmission from CH to MS

Queries which enables to use the same query to retrieve node values with different predicates thus resulting in less queries. On the other hand in traditional queries requires different queries for nodes that have different thresholds and hence incurs more number of queries.

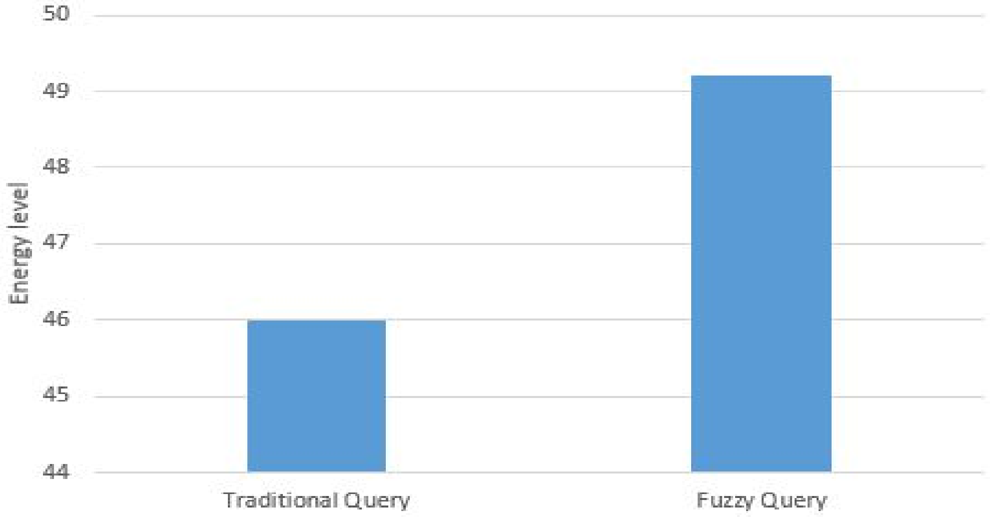


Fig. 6: Energy Level at Sink Node

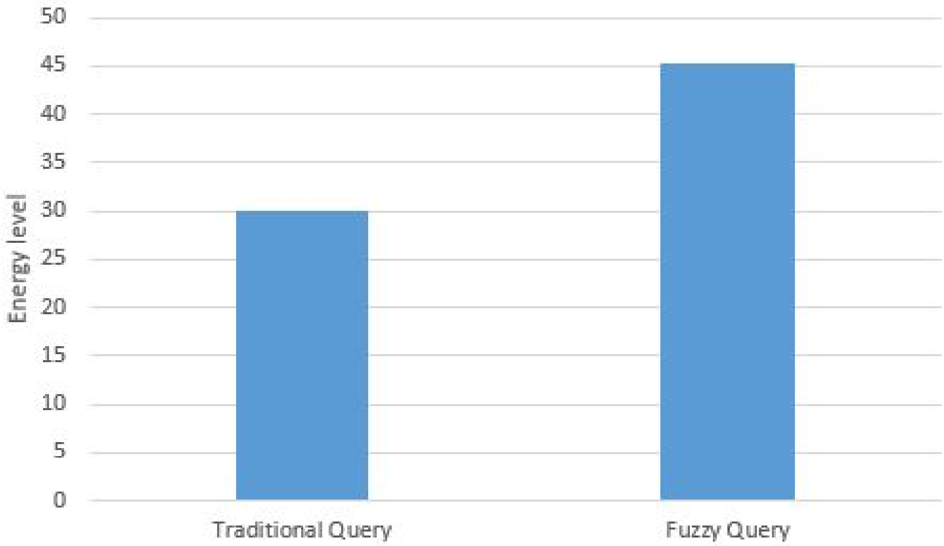


Fig. 7: Energy Level at MS

Fewer queries implies lesser transmissions and hence less energy is spent by the sensor node. Fig 6 and Fig 7 shows the overall energy consumption of the proposed fuzzy query proc-essing scheme with the traditional query processing system. Since the proposed system user fewer queries, energy consu -mption is very less compare to the traditional query processing approach.

V. CONCLUSION

This work presents fuzzy query processing system for animal health monitoring in wireless sensor networks. The key benefit of our approach is the use linguistic terms which allow the interpretation of data to be considered at each node using fewer queries and also it filters results locally inside the network, rather than requiring the application user to perform post-hoc analysis over the query results. The novel proposed routing strategy that involves heterogeneous nodes enables to disseminate the queries and collect the query results in a reliable manner in a mobile environment.

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