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A novel approach for smart cities in convergence to wireless sensor networks

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ABSTRACT

Internet of things (IoT) for Smart cities has been gradually bringing a sea of technological changes in our day to day life, which in turn helps to make our life more comfortable. Sensing and timely disseminating the information to the base station is the main feature in Internet of Things enabled applications. This function is carried out by the base layer of IoT paradigm and it is consisted of wireless sensor networks (WSNs). In this paper, we propose a WSN-IoT paradigm for real-time applications. The main focus is to find the means of providing information as early as possible to receiver which is prerequisite in smart cities. In this paper, routing is based on the shortest path which is selected using TOPSIS optimization and achieves balance between performance and energy consumption with regard to four criteria's: 1) Least distance of selected nodes from the base station, 2) Residual Energy, 3) minimum Euclidean distance between m^{th} selected node and 4) next optimum n^{th} node in the transmission range and number of neighboring nodes. Finally, Simulations are conducted in MATLAB in order to demonstrate how the proposed method would work to locate the best node in each cycle and confirm its effectiveness.

1. Introduction

IoT offerings are transforming cities by improving infrastructure, creating more efficient and cost effective municipal services, enhancing public transportation, reducing traffic congestion and keeping citizens safe and more engaged in the community. A wireless sensor network is an important element in IoT paradigm. The common vision related to the real world physical processes is usually associated with one single concept, the internet of things (IoT). Through the use of sensors, the entire physical infrastructure is closely coupled with information and communication technologies; where intelligent monitoring and management can be achieved via the usage of networked embedded devices. In the issues related to real world applications like forest fire detection, Smart city, Digital city, Traffic Accidents IoT has been realized as a vital solution. There are many challenges in the field of technological development of IoT. The main challenge is to resolve the problem of sending the sensed data through shortest path routing with energy efficient communication among sensor nodes. Various IoT components are mobile phones, RFID tags, Sensors, Video cameras for surveillance which are linked with internet with wired or wireless links. A wireless sensor network (WSN) is a network formed by a large number of sensor nodes where each node is equipped with a sensor to detect physical phenomena. Sensor nodes monitor the collected data to transmit to other sensor nodes by multi hop routing. During the process of transmission, monitored data after multi hop routing may be handled by multiple nodes to get to base station which leads to IoT. The most-characteristic attributes of nodes used in WSNs are the limited energy, storage ability and communication bandwidth required.

The research objective of this paper is to achieve green networking for conserving bandwidth that will ultimately reduce energy use and indirectly cost. So often various protocols viz clustering protocols (Bara'a and Khalil, 2012; Hussain, Matin, & Islam, 2007;Liu and Ravishankar, 2011; Norouzi, Babamir, & Zaim, 2011;Mahmood et al., 2013), MAC and Routing protocols (Tyagi and Kumar, 2013; Han, Jiang, Qian, Rodrigues, & Cheng, 2014; Younis and Fahmy, 2004), Ring based Cross layer protocols (Khalid, Yufeng, & Sankar, 2011; Mendes, Rodrigues, Lloret, & Sendra, 2014; Sanchez-Iborra and Cano, 2014; Hamrioui, Lorenz, Lioret, & & Lalam, 2013 Le and Hossain, 2008; Hangguan, Ho Ting, & Weihua, 2011; Rani, Malhotra, & Talwar, 2014; Rani and Ahmed, 2015) etc have been proposed in past but these inventions have not been examined the objects in consideration of energy efficient IoT for smart cities.ross layer routing model using TOPSIS for the deployment of IoT for smart cities. Cross layer Integration of MAC and routing protocol is the method used to reduce protocol overhead as

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the MAC layer is using the routing information from routing layer and MAC layer function is based on Adaptive sleeping. This reduces energy wastage due to collision and overhearing problem in the MAC layer based on adaptive sleeping. The TOPSIS optimization technique is used to locate the best node having shortest route to deliver the information to the base station. When a source node finds a shortest routing path based on ring based structure in its request zone using multiple attribute decision making (MADM) approach, it is found that it becomes more energy efficient as compared to traditional approaches for WSNs. Another additive feature of this protocol is that it can be easily implemented in energy efficient IoT as it eliminates cluster formation phase and direct communication from source node to base station using multi hop routing. Due to this feature it is more useful for real time applications like traffic signaling, fire detection, smart city projects where information with minimum delay is primary constraint.

Finally, Minimum energy consumption TOPSIS shortest path routing algorithm (TSPR) is executed which uses TOPSIS optimization to select the best node in the routing path for the optimization of energy parameters. Our contributions in this paper can be summarized below:

1. A ring based cross layer network for placement of network components, that is objects in the IoT is presented here. This network has Scalability and Minimum delay feature of IoT to extend it up to any level. The packet is sent from the source node to the base station from the outermost ring nodes following the optimum shortest route by selecting the next appropriate node within the transmission range in existing ring or in the next ring having lowest energy consumption in the network, minimum Euclidean distance between m^{th} selected node and next n^{th} node in the transmission range, minimum distance of the nodes in the next ring from the base station and cluster density. Direct communication between the nodes provides load balancing as no cluster head is chosen in this case, thus enhancing network lifetime.
2. TOPSIS optimization is applied for the proposed network structure in terms of Maximum throughput, minimum delay, load balance and increase in network lifetime for implementation of an efficient and scalable IoT for Smart cities.
3. With extensive simulations on randomly deployed sensor nodes, the proposed scheme is validated in comparison to the existing WSN schemes. It is found that this scheme is more favored for various applications of IoT like smart cities.

1.1. Enabling technologies

Communication services in the smart city as shown in Fig. 1, have raised some technical issues regarding communication between sensor nodes still have to be resolved. In the context of the Internet of Things (IoT), the communication between sensors nodes has to be wireless. Low power communication standards, suitable for an extremely large number of devices and their heterogeneity are necessary. In particular, depending on location and necessary coverage, there is various numbers of networks in smart cities. The existing communication services that are utilized in a Smart City infrastructure: LTE (Long term evolution), 3G (3rd generation), Wi-Fi (Wireless fidelity), WiMAX (worldwide interoperability for microwave access), Zig Bee, CATV (cable television) and satellite communication. The main motive is to connect all sorts of things (sensors and IoT's) that can help in making the life of citizens safer and comfortable.

The rest of paper is organized as follows. Section 2 provides the work related to the field of WSN. A detailed description of the TOPSIS optimization Technique is given in Section 3. Shortest path Identification in ring based Cross layer Protocol for IoT smart city application in wireless Sensor network using TOPSIS optimization is presented in Section 4. The results of different simulations are discussed in Section 5.We conclude our findings in Section 6.

2. Related work

A lot of research has already been reported in wireless sensor network for deployment of green IoT (Liu and Cao, 2012; Hodges et al., 2013; Rohokale, Prasad, & Prasad, 2011; Ehsan and Hamdaoui, 2012; Al-Fagih, Al-Turjman, Alsalih, & Hassanein, 2013) although the efficient communication was a key matter of concern but scanty work is found related to communication for a scalable and energy efficient IoT. In this section very brief review presented regarding some of the researchers used TOPSIS and other optimization techniques to optimize different parameters related to the field of wireless sensor networks for decision making. Many WSN routing and cross layer protocols were proposed in past such as PEGASIS (Jung, Han, & Chung, 2007), DEEC (Saini and Sharma, 2010), Mod Leach (Mahmood et al., 2013), SEP (Matta, 2004), EECHA (Kumar and Patel, 2011), EECS (Ye, Li, Chen, & Wu, 2005), CL-RS (Kusumamba, 2015), ALPL (Jurdak, Baldi, & Lopes, 2007), RAWMAC (Gonizzi, Medagliani, Ferrari, & Leguay, 2014), Area Cast (Heurtefeux, Maraninchi, & Valois, 2011) etc. The main objective of these protocols is to enhance the network lifetime which try to optimize the route with best cluster head selection and improve energy efficiency forming chains of nodes, by load balancing on the clusters. These routing algorithms neither compatible nor Scalable for IoT applications because of extra time needed to form clusters and cluster head selection as they introduce more complexity.

The most widely used Weighted Minimum Spanning Tree, Bee Algorithm-Simulated Annealing (BASA-WMST) (Saravanan and Madheswaran, 2014) routing protocols is the tree-based one. In this type of routing all nodes transmit data to one node that is a base station (BS). Many existing solutions like Decentralized Fuzzy Clustering Protocol (DFCP) (Moh'd Alia, 2014), E-CH tree (Tang, Zhou, Niu, & Wang, 2014) and multi-hop LQI (Diallo, Marot, & Becker, 2010) construct trees to route the data in a many-to-one pattern, but these solutions are not applicable for IoT applications like environment monitoring and coal mine goof applications. Other patterns required to be considered like many-to-many and one-to-many communication.

Fuzzy TOPSIS technique was used for the selection of cluster head which increases Network lifetime resulting in energy saving (Azad and Sharma, 2013). This paper presented Fuzzy and Ant Colony Optimization (ACO) based MAC/Routing cross-layer protocol (FAMACRO) for Wireless Sensor Networks that included cluster head selection, clustering and inter-cluster routing protocols. The results shows that the proposed improved Fuzzy technique i.e. FAMACRO is 82% more energy efficient and increases network lifetime by 5% to 30% more compared to DEEC, UHDEEC but they do not consider the essential feature of load balancing and scalability for IoT (Gajjara and Sarkarb, 2015). This paper used the TOPSIS MADM algorithms and provided analysis regarding the causes of the rank reversal. The results revealed that the new techniques completely eliminate the ranking abnormalities, in both cases regardless of the number of parameters while networks disappear and when new networks are discovered (Abdelkrim Senouci, Sajid Mushtaq, Hoceini, & Mellouk, 2016). Ranking of influential nodes can be looked as a multi-attribute decision making (MADM) problem to some extent. As a result, to comprehensively combine different attribute data of each node is treated as important entity. Evidence theory is widely used to identify influential nodes in complex networks due to the efficient modeling and fusion of uncertain information (Cuzzolin, 2008; Jiang, Yang, Luo, & Qin, 2015; Deng, 2015; Su, Mahadevan, Xu, & Deng, 2015; Deng, Hu, Deng, & Mahadevan, 2014; Wei, Deng, & Zhang, 2013; Hua, Dua, Mob, Wei, & Denga, 2016) but do not consider delay factor i.e. timely delivery of data. TOPSIS technique which is capable of using multiple individual metric and implemented as a distributed protocol in which each node makes its decision based on local information only. The simulation results shows that the proposed technique comparatively resulting in a significant increase in network lifetime to all other well-known protocols including LEACH, EECS and HEED (Aslam, Philips, Robertson, & Sivakumar, 2011). But with the

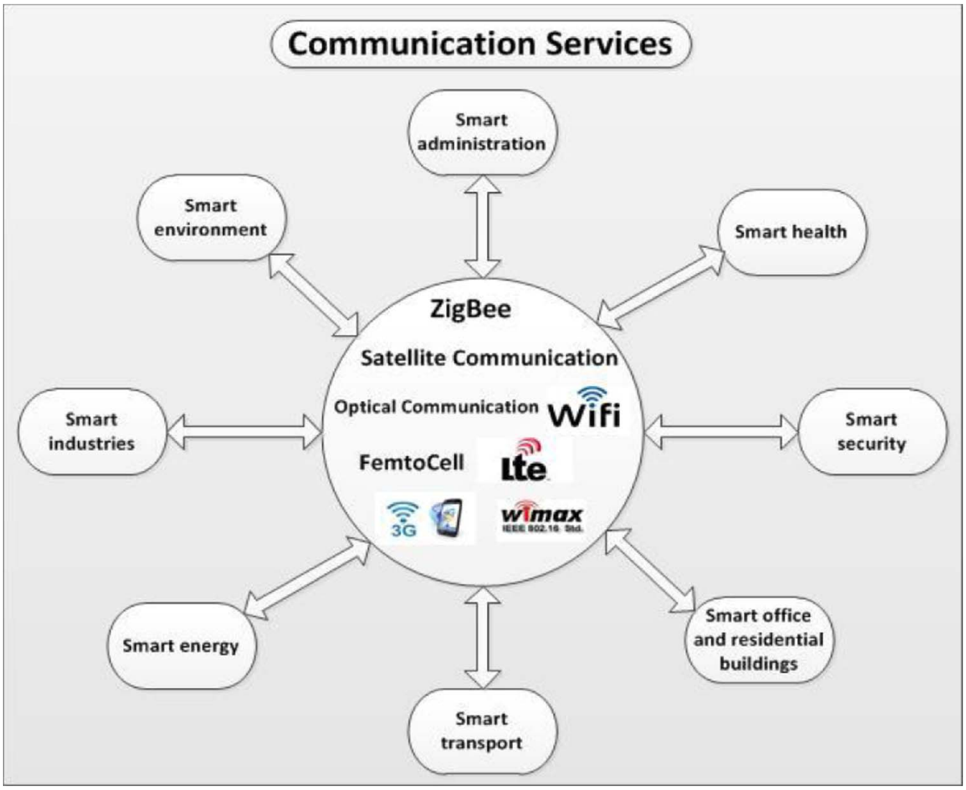

Fig. 1. Communication Services.

increase in network size their efficiency decreases so they are not suitable for TOPSIS technique even used in medical decision-making and could reduce unnecessary costs. The fuzzy axiomatic design with risk factors (RFAD) approach was used in multi attribute comparisons of medical imaging systems in hospital to integrate the risk factors in each criterion and calculated the information content to compare alternatives (Kulak, Guner Goren, & Supciller, 2015). Since WSNs have various applications, such as environmental monitoring, military and natural disaster detection, structural health monitoring etc (Li, Wang, & Guo, 2010) and of course limited power and energy is available due to the compactness of wireless SNs, hence the efficient and effective utilization of energy in WSNs is required (Lhadi, Rifai, & Alj, 2014). In this paper, a ring based routing protocol EEIMRP (Jain, Malhotra, & Brar, 2016) is proposed for wireless sensor networks. Each ring has given ring identification number starting from the innermost ring. Cross layer Integration of MAC and routing EEIMRP protocol is the method to reduce protocol overhead as the routing information from routing layer is used by MAC layer to find the duty-cycle of each node, this protocol also reduces energy wastage due to collision and overhearing problem in the MAC layer based on adaptive sleeping. When a source node finds a shortest routing path based on ring based structure in its request zone using EEIMRP protocol and it allows only nodes belonging to shortest routing path to be awake while permitting other nodes in the zone to sleep mode. Today, One of the most emerging field is the deployment of wireless sensor networks in Smart City architecture (Gaura, Bryan Scotneya, Parr, & Mc Cleana, 2015) has led to very large amounts of data being generated each day across variety of applications including home automation, healthcare monitoring industrial automation and traffic monitoring. The author proposed the services that are commonly associated to the Smart City vision and that can be enabled by the

Deployment of an urban IoT (Zanella, Bui, Castellani, Vangelista, & & Z. Michele, 2014). On the technical side, the most important issue consists in the non-interoperability of the heterogeneous technologies currently used in city and urban developments. In this respect, the IoT vision can become the building block to practically realize a unified urban scale ICT platform, thus unleashing the potential of the Smart City vision (Hernández-Muñoz et al., 2011; Mulligan and Olsson, 2013) variety of domains. The IoT concept, hence, aims at making the Internet even more immersive and pervasive by enabling easy access and interaction with a wide variety of devices such as for instance, home appliances, surveillance cameras in cities, vehicles and actuators (Bellavista, Cardone, Corradi, & Foschini, 2013).

Every problem has number of alternative solutions hence decision making always remains an important issue while selecting the best solution among the alternatives. Apart from having different types of protocols, a common problem lies in the same that how effectively a best solution is to be found among the alternative solutions. So the researchers implemented different optimization techniques to solve the complex problems.

The objective of all the above mentioned Optimization techniques is the selection of cluster head but they do not consider the shortest path routing.

In this paper to get best results, an optimization technique called TOPSIS is implemented to identify the shortest path in ring based cross layer Protocol for wireless sensor network. The value of each attribute in the matrix is normalized. As far as we are concerned, no algorithm for constructing a shortest multi hop path using TOPSIS optimization for WSNs has yet been proposed. The proposed algorithm generates energy efficient shortest path in order to be used for fault-tolerance or load-balancing.

Based on the above literature survey, it is identified that existing schemes lack in energy efficiency, Scalability, timely delivery of data and reliability for WSN based IoT applications. With this objective in mind, TSPR algorithm for WSN/IoT applications is proposed.

3. Description of TOPSIS

The TOPSIS method is one of the most widely used MCDM methods. The basic principle of TOPSIS method is that the best alternative should have the shortest distance from the positive ideal solution and the farthest distance from the negative ideal solution. Fig. 2 shows the flow

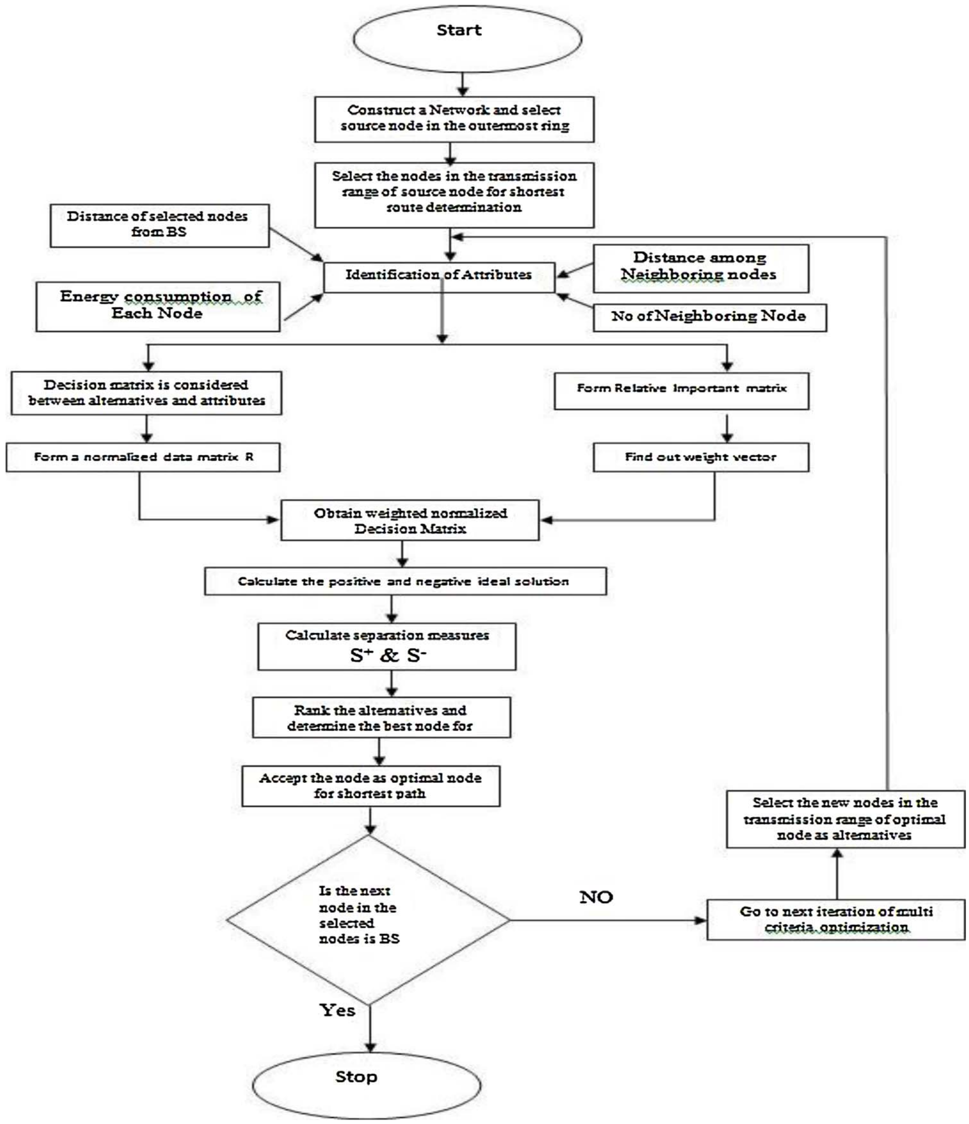

Fig. 2. Flow Chart for Proposed Method.

chart of our method. The detailed description of the proposed method is as follows:

3.1. Step-1 creating the matrix

n nodes with m attributes are represented in the form of a matrix as follows:

$$D_i = \begin{bmatrix} x_{11} & x_{12} & x_{13} & \dots & x_{1n} \\ x_{21} & x_{22} & x_{23} & \dots & x_{2n} \\ x_{31} & x_{32} & x_{33} & \dots & x_{3n} \\ x_{m1} & x_{m2} & x_{m3} & \dots & x_{mn} \end{bmatrix}$$

x_{ij} Represents the value of j_{th} attribute for the i_{th} node, where

$\{i = 1,2,3 \dots n\},\{j = 1,2,3 \dots m\}$.

3.2. Step-2 normalize the decision matrix

The normalization of the decision matrix is done using the below transformation for each r_{ij}.

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{n} x_{ij}^2}} \tag{1}$$

Each Attribute in the matrix is assigned a weight w_j then the weights will be multiplied to normalized matrix.

$$v_{ij} = w_j * r_{ij} \quad \text{Where} \quad \sum_{j=1}^{n} w_j = 1 \tag{2}$$

3.3. Step-3 determine the positive and negative ideal alternatives

The Positive ideal Solution and negative ideal Solution are defined according to weighted decision matrix as follows:

$$A^+ = \{v_1^+, v_2^+ \dots\dots\dots\dots v_n^+\}$$

$$A^+ = \{(\max v_{ij} | i = 1,2 \dots\dots\dots\dots m), j = 1,2 \dots n\} \tag{3}$$

Positive attribute: The one which has the best attribute values (more is better) and $A^- = \{v_1^-, v_2^- \dots\dots\dots\dots v_n^-\}$

$$A^- = \{(\min v_{ij} | i = 1,2, \dots\dots\dots\dots m), j = 1,2 \dots n\} \tag{4}$$

Negative attribute: The one which has the worst attribute values (less is better).

3.4. Step-4 obtain the separation measure (based on Euclidean distance) of the existing alternatives from ideal and negative one

$$S^{+} = \sqrt{\sum_{j=1}^{n} (v_j^{+} - v_{ij})^2} \qquad i = 1, 2\ldots m,\ j= 1, 2\ldots n \tag{5}$$

$$S^{-} = \sqrt{\sum_{j=1}^{n} (v_j^{-} - v_{ij})^2} \qquad i = 1, 2\ldots m,\ j= 1, 2\ldots n \tag{6}$$

3.5. Step-5 rank the alternatives

TOPSIS rank indices are estimated as:

$$CC_i = \frac{S_i^-}{S_i^+ + S_i^-} \qquad 0 \le CC_i \le 1$$

The TOPSIS algorithm is applied to select the best node to identify shortest path in the wireless sensor network from the node in outer ring to the sink. The procedure is repeated for locating the next more energy efficient node with shortest distance from the base station.

4. Identifying shortest path in ring based cross layer protocol for IoT smart city application in wireless sensor network using TOPSIS optimization

In the proposed protocol the ring system has been developed in which every node has a ring no. and while selecting the next hop candidate the node will always select the node from next ring or within same ring in the transmission range.

4.1. Model description and assumptions for IoT framework

1. 100 nodes are generated randomly in 200*200 m^2 area.
2. Each sensor node has given unique identity number.
3. The Base station is located at the center of field.
4. The packet is sent from the source node to the base station from the outermost ring nodes following the optimum shortest route by selecting the next appropriate node within the transmission range in existing ring or in the next ring having Maximum Residual Energy, minimum Euclidean distance between m^{th} selected node and next n^{th} node in the transmission range, Minimum distance of the nodes in the next ring from the base station and cluster density. Fig. 3 shows the network model disseminating the information from source node to base station choosing the Optimum Shortest distance using TOPSIS.
5. A Friss radio model as in (Heinzelman, Chandrakasan, & Balakrishnan, 2003) is used. Transmission Eq. (7) and reception Eq. (8) are used to calculate energy consumed. It is also assumed for free space model distance between transmitter and receiver is d^2. For multipath fading channel distance is d^4. Thus, to transmit an l-bit message at distance d, the equation is

$$E_{Tx}(l, d) = E_{elec}{*}l + \varepsilon_{fs}{*}l{*}d^2 \qquad d < d_{thres}$$

$$E_{Tx}(l, d) = E_{elec}{*}l + \varepsilon_{mp}{*}l{*}d^4 \qquad d > d_{thres} \tag{7}$$

Where the threshold is

$$d_{thres} = \sqrt{\frac{\varepsilon_{fs}}{\varepsilon_{mp}}} \tag{8}$$

To receive the l-bit message, the equation is given by

$$E_{Rx}(l) = l{*}E_{elec}$$

$E_{RX}(l)$ is the energy spent in reception of a l-bit message, E_{elec} is the base energy required to run the transmitter or receiver circuitry. Table 1 shows the simulation parameters used in the present study.

Let us assume m^{th} node is selected in the outermost ring as shown in Fig. 2. Consider a matrix D = $x_{mn,}$ the first columns represents the value of least distance of the selected nodes from the sink. The second column represents the distance of neighboring nodes, the third column represents the maximum residual energy and the last column represents the number of neighboring nodes in the selected area.

5. Results and discussion

In network model the packet is sent from source node to the base station from the outermost ring nodes following the optimum shortest route by selecting the next appropriate node within the transmission range in existing ring or in the next ring. In each cycle starting from the outermost ring, the best node in the shortest path is selected using TOPSIS optimization. In the present study the network is divided into four rings, the optimal nodes are selected on the basis of four criteria including least distance of selected nodes from the base station, Maximum residual energy, minimum Euclidean distance between m^{th} selected node and next n^{th} node in the transmission range and number of neighboring nodes. For an example a stepwise working of system model is detailed below by calculating the best node in the transmission range of source node in first cycle for the second outer ring. The similar calculation is performed in each cycle for selecting the best node.

5.1. Step 1

Consider the decision matrix D = (x_{mn}) for sensor nodes those are in transmission range of source node in the second outer ring. As shown in Fig. 3 the nodes those are in red color are in transmission range and numbered as N1 to N8.The best node is selected by TOPSIS out of these eight nodes in the shortest path, by considering four criteria in the network as shown in Table 2.

$$D = \begin{bmatrix} 31.3847 & 72.4224 & 1.97 & 5 \\ 34.1321 & 71.1688 & 2.33 & 6 \\ 37.2156 & 59.0399 & 2.77 & 7 \\ 36.4005 & 62.3939 & 2.65 & 5 \\ 33.0151 & 63.1981 & 2.18 & 6 \\ 23.0868 & 73.437 & 1.066 & 4 \\ 37.6431 & 73.4098 & 2.834 & 5 \\ 37.1214 & 59.6825 & 2.756 & 7 \end{bmatrix}$$

5.2. Step 2

The normalized matrix (R) is calculated according to Eq. (1)

$$R = \begin{bmatrix} 0.353106 & 0.381558 & 0.291985 & 0.309492 \\ 0.384016 & 0.374953 & 0.345342 & 0.371391 \\ 0.418708 & 0.311052 & 0.410557 & 0.433289 \\ 0.409538 & 0.328723 & 0.392771 & 0.309492 \\ 0.371449 & 0.33296 & 0.32311 & 0.371391 \\ 0.259747 & 0.386904 & 0.157998 & 0.247594 \\ 0.423518 & 0.38676 & 0.420043 & 0.309492 \\ 0.417648 & 0.314438 & 0.408482 & 0.433289 \end{bmatrix}$$

5.3. Step 3

The weights (0.2, 0.3, 0.4 and 0.1) were assigned according to the preference of the individual criteria. Minimum Euclidean distance between m^{th} selected node and next n^{th} node in the transmission range, least distance of selected nodes from the base station, Maximum Residual energy and number of neighboring nodes respectively. Then each attribute in the matrix is assigned a weight w_j then the weights will be multiplied to normalized matrix according to Eq. (2).

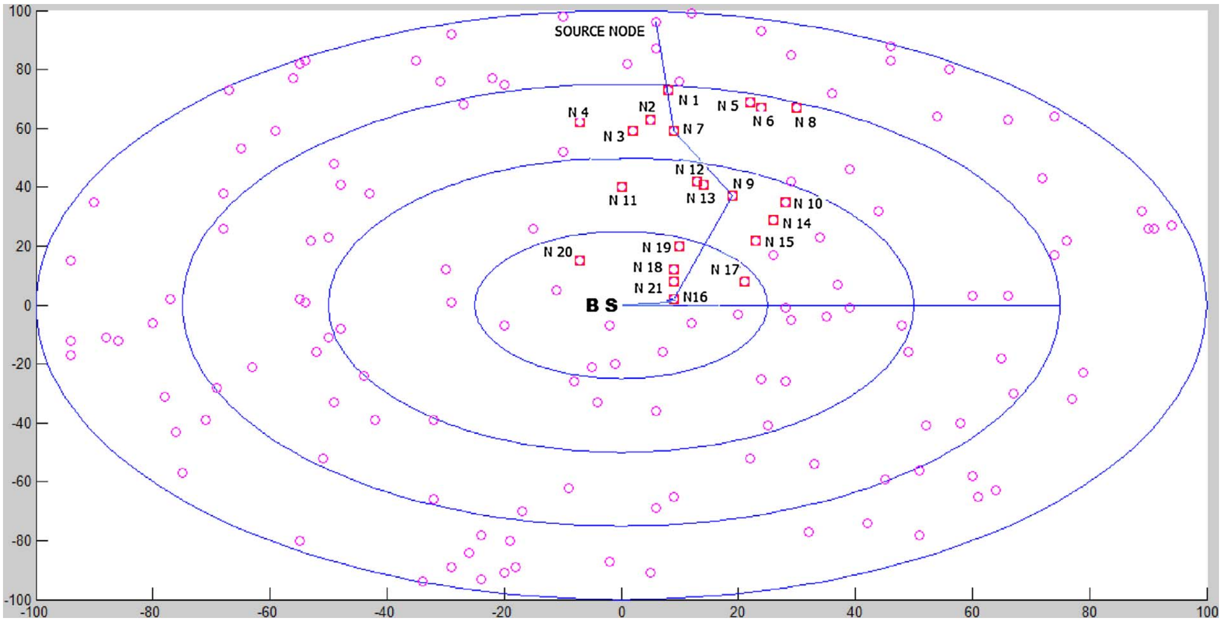

Fig. 3. Network Model.

Table 1
Simulation Parameter.

Symbol	Value
N	100
Area	200*200m^2
BS location	(0,0)
ε_{fs}	10pj/bit/m^2
ε_{mp}	0.0013pj/bit/m^4
E_o	5J
E_{elec}	50nJ/bit
Packet size	1Kbyte
Transmission Range	25m

Table 2
Elements of Decision Matrix.

Node number	Distance from neighboring node	Distance from base station	Residual Energy	Number of neighboring nodes
N1	31.3847	72.4224	1.97	5
N2	34.1321	71.1688	2.33	6
N3	37.2156	59.0399	2.77	7
N4	36.4005	62.3939	2.65	5
N5	33.0151	63.1981	2.18	6
N6	23.0868	73.437	1.06	4
N7	37.6431	73.4098	2.83	5
N8	37.1214	59.6825	2.75	7

$$V=\begin{bmatrix} .070621 & .114467 & .116794 & .030949 \\ .076803 & .112486 & .138137 & .037139 \\ .083742 & .093316 & .164223 & .043329 \\ .081908 & .098617 & .157109 & .030949 \\ .07429 & .099888 & .129244 & .037139 \\ .051949 & .116071 & .063199 & .024759 \\ .084704 & .116028 & .168017 & .030949 \\ .08353 & .094331 & .163393 & .043329 \end{bmatrix}$$

5.4. Step 4

The positive ideal solution and negative ideal solution are calculated according to Eqs. (3) & (4) respectively.

$$A^{+} = \{.084704 \quad .116071 \quad .168017 \quad .043329\}$$

$$A^{-} = \{0.051949 \quad 0.093316 \quad .063199 \quad .02475\}$$

5.5. Step 5

The separation measures of the existing alternatives from positive ideal solution and negative ideal solution were obtained according to Eqs. (5) & (6) respectively.

$$S^{+} = \sqrt{\begin{aligned}&((0.084704 - 0.070621)^2 + (0.116071 - 0.114467)^2 \\ &+ (0.168017 - 0.116794)^2 + (0.043329 - 0.030949)^2\end{aligned}}$$

$$S^{+} = 0.054571$$

Table 3
TOPSIS Analysis to locate first best node in shortest path.

Node number	Distance from neighboring node	Distance from base station	Residual Energy	Number of neighboring nodes	S^{+}	S^{-}	$CC_{i\ \mathrm{Rank}}$
N1	31.3847	72.4224	1.97	5	0.0545	0.06088	0.52733
N2	34.1321	71.1688	2.33	6	0.0317	0.08218	0.72149
N3	37.2156	59.0399	2.77	7	0.0230	0.10752	0.82322
N4	36.4005	62.3939	2.65	5	0.0241	0.09890	0.80354
N5	33.0151	63.1981	2.18	6	0.0437	0.07111	0.61924
N6	23.0868	73.437	1.06	4	0.1113	0.02275	0.16965
N7	37.6431	73.4098	2.83	5	0.0123	0.11231	0.90071
N8	37.1214	59.6825	2.75	7	0.0222	0.10668	0.82738

Table 4
TOPSIS Analysis to locate second best node in shortest path.

Node number	Distance from neighboring node	Distance from base station	Residual Energy	Number of neighboring nodes	S^+	S^-	$CC_{i\ Rank}$
N9	39.5601	31.8277	3.1300	10	0	0.22496	1
N10	21.0238	40.0000	0.8840	7	0.0161	0.03565	0.6885
N11	17.4642	43.9659	0.6100	5	0.0268	0.0356	0.5562
N12	18.6815	43.3244	0.6980	6	0.02150	0.03339	0.6082
N13	30.6105	44.8219	1.8740	6	0.02150	0.11938	0.8473
N14	24.1661	41.5933	1.1680	6	0.02150	0.058017	0.7295
N15	34.4819	38.9487	2.3780	8	0.01075	0.15991	0.937

Table 5
TOPSIS Analysis to locate third best node in shortest path.

Node number	Distance from neighboring node	Distance from base station	Residual Energy	Number of neighboring nodes	S^+	S^-	$CC_{i\ Rank}$
N16	36.4005	9.2195	2.65	1	0.1054	0.1715	0.6192
N17	29.0689	22.472	1.69	2	0.0844	0.13065	0.6075
N18	26.9258	15.000	1.45	1	0.0946	0.07704	0.4488
N19	34.0588	16.552	2.32	3	0.1401	0.15828	0.5304
N20	19.2354	22.3607	0.74	1	0.0648	0.09467	0.5934
N21	30.6757	12.0416	1.88	2	0.1243	0.10763	0.4638

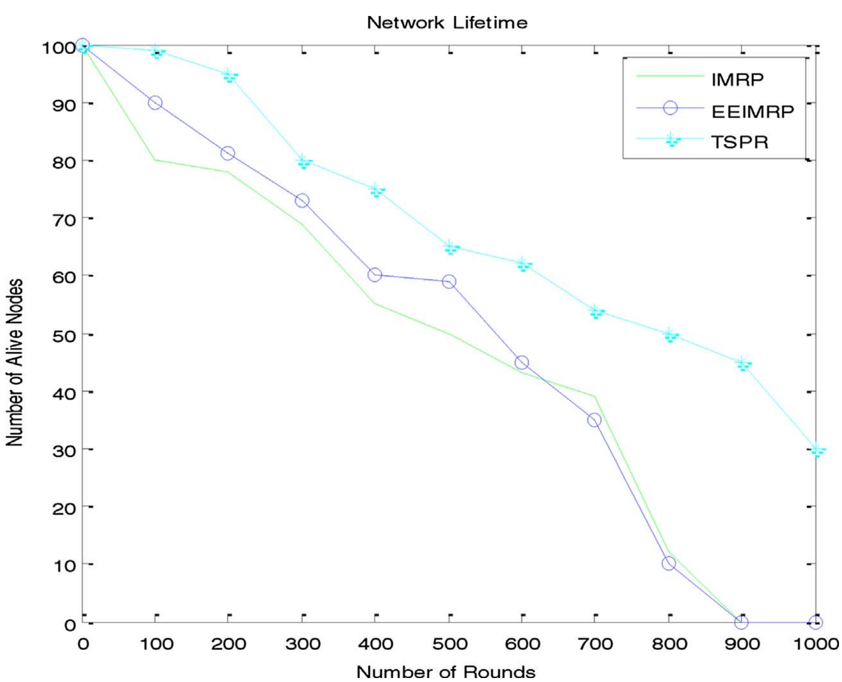

Fig. 4. Network Lifetime of generated paths by IMRP, EEIMRP and TSPR algorithms.

$$S^- = \sqrt{(0.05194 - .07062)^2 + (0.093316 - 0.11446)^2 + (0.063199 - 0.116794)^2 + (0.02475 - 0.030949)^2}$$
$$S^- = 0.060883$$

5.6. Step 6

The Relative closeness to the ideal solution was obtained by using Eq. (7) and results are shown in table

$$CC_i = \frac{.060883}{.060883 + .054571} = 0.5273$$

Finally by using the proposed TOPSIS optimization it is found that the node N7 is selected as a best node in the second outermost ring having shortest route as being closest to positive ideal solution. The cycle is repeated from step 1 to step 6 to locate next node in the routing path to base station for shortest route (Table 3).

To find the best node in third ring and innermost ring the steps 1–6 was repeated and the calculations are shown in Tables 4 and 5. It was revealed that N9 and N16 are the best nodes in the third and innermost ring respectively.

Fig. 4 shows the life time of the network. EEIMRP and the proposed technique TSPR significantly improve the life of the network compared to IMRP. Fig. 4 shows the number of rounds versus number of alive nodes graph. It can be noticed that all the nodes are dead after 900 rounds in case of IMRP and EEIMRP whereas in case of TSPR 30 nodes are still alive after 1000 rounds. Thus energy savings are significant in the TSPR algorithm as compared to previous methods. Thus Network lifetime of the proposed method is improved compared with IMRP and EEIMRP. This is due to using TOPSIS method which found Optimized path and results in energy saving of the Network.

The protocol TSPR in this paper is proved to be energy efficient with TOPSIS optimization. Fig. 5 shows the throughput versus number of rounds. It can be noticed that TSPR protocol has maximum throughput

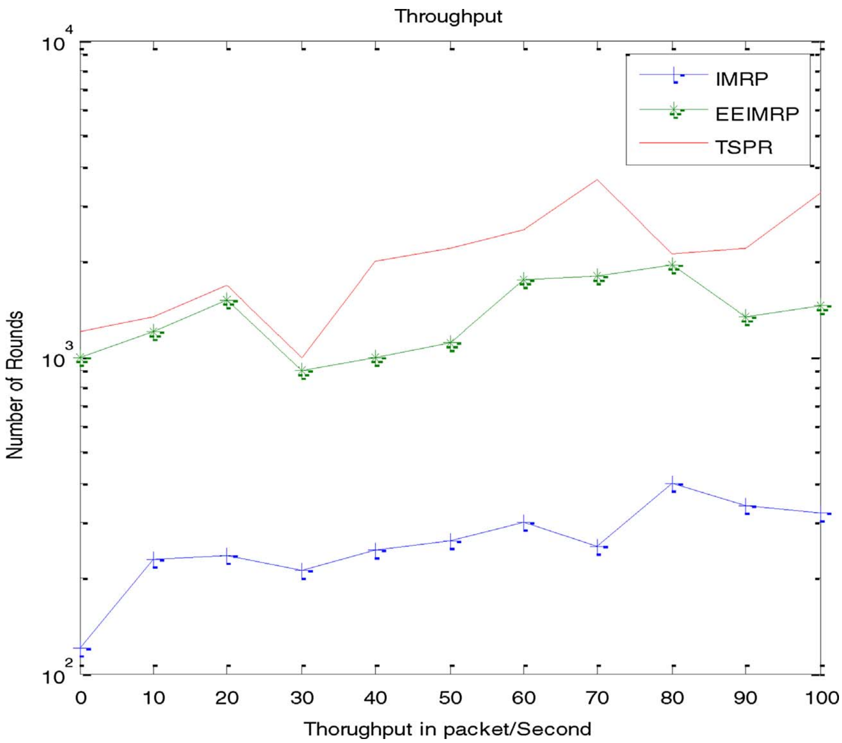

Fig. 5. Throughput of generated paths by IMRP, EEIMRP and TSPR algorithms.

up to 4000 rounds whereas in case of EEIMRP maximum throughput is up to 2000 rounds and in IMRP the maximum is up to 500 rounds only.

6. Conclusion

The effectiveness of any smart city enabled application depends upon the life time, accuracy and timely relaying of the information needed. The decision making plays an important role in selecting the shortest path in contrast with energy consumed in WSN's for enhancing the life time and MADM algorithms are a popular and widely accepted decision making tool. In this paper, we used a novel shortest path selection method TOPSIS for WSN-IoT paradigm for smart city. As far as we are aware, no one has yet proposed an algorithm which constructs a shortest path using this optimization technique. Simulations were performed, and the results show that adopting the new technique reduces or completely eliminates the chance of selecting the other alternative among the existing instead of choosing the best alternative, regardless of the number of parameters. From the result of the simulation, the proposed solution can achieve a global communication optimum and outperforms existing shortest path algorithm for wireless sensor networks. The novel cross-layer module is a primary step towards providing efficient and reliable end-to-end communication in IoT-WSN.

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