Path and Partner Selection in Unstructured Resource-Constrained Environments Based on Node Psychology in the Context of IoT

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Abstract – **Internet of Things (IoT) is the network of the huge number of resource-personated nodes whose main feature is the reliable communication and fast data exchange among devices in any network topology. In the upcoming world of internet, proper selection of desire or appropriate destination node and finding the optimized path from the huge number of the activated nodes is a very important task. Here many nodes are available in one or more hop distance and each node has various network parameters in the IoT world, so the selection of best path and nodes is quite complex. For this reason, we need to develop an algorithm to find out the best path towards the destination node considering significant network parameters. This paper proposes a general algorithm considering any network topology for discovering the path towards the destination node from the source node and give a solution to the contradiction which may arise if there is more than one consonant path. The proposed algorithm considers the node property of all node for calculating the behavior value, path influence behavior value and finally discover the optimized path from source node to destination node. The proposed algorithm is also evaluated by simulation to determine the impact of parameters in path determination.**

Key words- Node, Path and Partner selection, Path Influence Behavior, Node Parameter, IoT.

I. INTRODUCTION

In a cooperative service scenario like IoT, where many nodes are present in the IoT field, the most appropriate node selection can be a complex task for transmission of data [1]. Nowadays, IoT is the rising technology in scenarios such as smart city, smart home, eHealth, service, etc. Information is generally carried over by lossy networks and low power consists of smart nodes, many of those have limited power capacity and processing capability, and over very dynamic IP-based connections [1]. IoT operation depends on the identification, automatic management and use of a huge number of diverse physical and virtual objects (i.e. both physical and virtual representation), connected to the Internet [2], [3]. Additionally, the identification of a particular object and its addressing scheme ability to dynamically configure their addresses is also an open issue [4].

Because of many available nodes in network topology, proper selection of nodes and path is an important decision for data exchange between nodes to nodes. Therefore, the behavior of nodes may be changed after a certain time period. Also, the influence behavior of nodes may differ depends on specific communication service requirements. In IoT research field, the behavior of path and node selection is still in the initial stage. If a node wants to start communication, there may be a destination node is defined or not. Another case is that destination partner can be far away one or more than one hop distance. Some research work has been done on node discovery, node interpretation, and established the connections among available nodes in the world of IoT [5], [6].

A representation for the discovery and selection of a node in large-scale, resource-constrained environments in the context of service and application requirements was proposed and assessed [5], [6]. This representation relies on a fundamental mathematical approach which describes and predicts the positive outcome of human interactions and communications in terms of long-term relationships and recognizes various key variables in resource-constrained environments [5], [6]. The methodology is used to develop this model adopted from [7]. The mathematical model of the network parameters, such as Device Class, Influence function and Influence behavior are shown in [5], [6]. Three network architectures are proposed for data storage and reliable communication in the context of IoT [5]. An algorithm named “choosing a partner" is proposed in [6] and extended in [5]. An algorithm named “the behavior of a whole path” is proposed in [5], but there are some limitations. Also, a new priority of node called Emergency Priority and a new parameter called Reliability & service type properties proposed and performed simulations on behavior parameters and convergence of the behavior value [5].

The following paper proposes an algorithm for node selection and path evaluation based on path influence behavior, behavior value, node parameters, which is applicable for any kind of network topology either destination node is one hop or more hop distance and help us to find the optimized path. There was no such algorithm for path and partner selection in [5], [6].

The rest of the paper organized as follows: Section II addresses the related works. Proposed Methodology is represented in Section III. Section IV describes our experimental evaluation, Section V provides the conclusion of the proposed paper and Section VI suggests some future work over the algorithm.

II. BACKGROUND

A.Node Parameters:

Here we consider some IoT node parameters which help us to evaluate the fastest and best path to communicate among nodes [5] [6]. The Node parameters are shortly described here:

Device Class: Device Class is a number which indicates the potentiality of the node. It is composed of resource parameters (device speed, processing power, data storage, battery life, digression from the power efficiency defined by the throughput, manufacturer). The range of Device Class is [4; 20] where 4 means low power device and 20 means high power device.

Free Resources: Free resources is another node parameter which discloses the actual free resources present in that node. The range of free resources is [0; 0.9] where 0 means 100% of the resources are occupied and 0.9 means 100% of the resources are free.

Reliability Score: Before any communication, the source node needs to know how reliable the candidate nodes. The *Reliability* is another IoT node parameter which gives information that how reliable a node is. For IoT node, we use reliability instead of security. The range of Reliability parameter is between [1; 10] where 1 means least reliable and 10 means most reliable.

Influence Function: Another most important node parameter is Influence function. It is a function of Influence Behavior which indicates the influence of one node has on its partner. It is also used in the evaluation process of communication is described in [5], [6] with its score and description.

B. Modelling Node Interaction:

In [5] [6], the authors introduced a mathematical model which is used to define the *Influenced Behavior* scores. It is a score showing the strength of a node depending on its available resources and the demands it has to meet. The relationship equation of this mathematical model is given below:

$$N_{1(t+1)} = I_{N_2 N_1}(N_2)t + r_1 N_{1\,t} + a \qquad (1)$$
$$N_{2(t+1)} = I_{N_1 N_2}(N_1)t + r_2 N_{2\,t} + b \qquad (2)$$

Where N_1 is the Influence behavior of Node 1 and N_2 is the behavior score of Node 2. The details of the above equations are described in [5], [6]. Behavior has an only positive value and this value is used in connection establishment among nodes.

C. Algorithm for choosing a partner:

An algorithm for choosing a new partner in IoT topology was proposed in [6] which was extended in [5] including Reliability parameter. When a node wants to communicate with another node away from one hop distance and there is no fixed destination node, this algorithm is used to find out the appropriate partner node from the available nodes. At first, the source node calculates its uninfluenced behavior score and then sends the application requirements to its all neighbor nodes in one hop interval. The neighbor nodes receive the requirements and send back their own Device Class and influence behavior score to the source node. Then the source nodes choose the best partner node considering the Behavior value, Device Class and Reliability score.

D. The Behavior of a whole path:

A procedure for establishing an entire path and calculate behavior score named “Behavior of a Whole Path” was described in [5]. By this mechanism, we can calculate the Behavior value of the node to node communication and used it in the further calculation. For a specific proposed scenario, source node broadcast its requirements towards all its neighbors. Neighbor nodes of the source node modified the requirements and broadcast to their neighbors and so on. When the destination node receives the requirements it calculates its own behavior value and sends this value towards the node of the previous path. Then, a node of the downstream path calculates the path influence behavior.

The weak points of this algorithm are:

- This mechanism is only applicable to the proposed scenario shown in [5]
- There is no exact algorithm without only a scenario model.
- If there is more than one candidate path, this algorithm can’t give any solution.

III. PROPOSED METHODOLOGY

A. SYSTEM ARCHITECTURE:

The proposed methodology is applicable for any kind of network topology. Here, we consider the following network topology, for example,

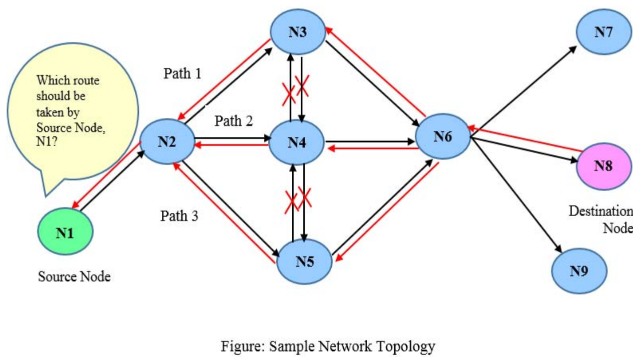

Fig. 1: A network topology contains 9 nodes

In the scenario, Source node N_1 wants to find a reliable path towards Destination node N_8.

There are three possible paths -

1. $N_1 \rightarrow N_2 \rightarrow N_3 \rightarrow N_6 \rightarrow N_8$
2. $N_1 \rightarrow N_2 \rightarrow N_4 \rightarrow N_6 \rightarrow N_8$
3. $N_1 \rightarrow N_2 \rightarrow N_5 \rightarrow N_6 \rightarrow N_8$

We propose the following algorithm to choose an optimal path by the Source node to communicate with the Destination node for exchanging the data.

B. PROPOSED ALGORITHM:

The proposed algorithm Path and Partner Selection in Unstructured Resource-Constrained Environments Based on Node Psychology in the Context of IoT is applicable for any kind of network topology. This algorithm is applicable for one hop or more hop distance and also can give an exact solution if there is more than one candidate path.

The steps of the algorithm are as follows:

1. Appended the network parameters with the nodes present in Network Topology.

2. Define the Source node (N_s) and the Destination node (N_D) among all the nodes.

3. Setup Quality of service (QoS) requirements for the Source node. Quality of service means application requirements which are essential for any application. Suppose, for a certain application, source node needs Delay 500ms, Throughput 1.5Gbps.

4. Source Node (N_s) wants to find a path to the Destination node (N_D) (n hop distance).

5. N_S sends a package including its application requirements, the name of destination node as header to its neighbors.

6. Neighbor nodes modify requirements and forward packets to their neighbors and continue.

7. N_D receives requirements and identifies itself as a final destination, calculates its influenced behavior based on the modified requirements and replies the packets along with the previous path.

8. Every node in the path calculates the path influence behavior, an average of its influence behavior and the influence behavior of the previous neighbor node.

9. N_D receives feedback.

10. It checks whether there is one path having the highest Influenced Behavior or not:

a. If Yes, a path is found;
The source node can communicate with the destination node through this path.
b. If No, continue to Step 11;

11. The node analyzes whether the nodes with an equal highest value of the Influenced Behaviors are from the same Device Class or not:

a. If Yes, continue to Step 13;
b. If No, continue to Step 12;

12. The capable partners with the highest scores for the Influenced Behaviors and with the highest value for the Device Class among all potential partners are saved.
Continue to Step 10;

13. Choose the potential partner(s) with the highest value of the Reliability score

14. The node checks whether there is only one potential partner left or not:

a. If Yes, a partner is found;
b. If No, a partner is picked randomly from the remaining pool of partners.

C. REQUIRED EQUATIONS:

Influence Behavior Score:

$$N_{1(t+1)} = I_{N2\rightarrow N1}(N_{2t}) + r_1 N_{1t} + a \qquad (3)$$

$$N_{2(t+1)} = I_{N1\rightarrow N2}(N_{1t}) + r_2 N_{2t} + b \qquad (4)$$

Uninfluenced Behavior:

$$B_{UB} = \frac{Device\ Class}{1 - Free\ Resources} \qquad (5)$$

Influence Function:

$$I = \alpha I_L + \beta I_D + \gamma I_{PE} + \delta I_S + \varepsilon I_T + \zeta I_R + \eta I_{PDR} + \theta I_{BS} + + \iota I_J + \kappa I_{CP} + \lambda I_{EP} + \mu I_{IC} + \nu I_{DC} \qquad (6)$$

Path Influence behaviour:

$$PIB = \frac{I_{Current\ Node} + I_{Adjacent\ Node}}{2} \qquad (7)$$

IV. Experimental Evaluation

A. Sample Input:

The network topology contains 8 nodes. N_1 is the source node and N_8 is the destination node. The node parameter (Device Class, Free resources, Reliability score and Influence behavior) are given for all 8 nodes. The Quality of Service (Delay time, Latency, Throughput, packet delivery ratio, etc.) are attached to the source node. It is not obvious that all quality of services is required for any communication. Only the interested parameters are set up for distinct communication. The requirements for any service is delivered from source node towards all the nodes in the network topology. The proposed algorithm is applied to the network topology [Fig. 1] and we will get the best path for communication.

B. Numerical Example:

Influence Function,

$$= \alpha I_L + \beta I_D + \gamma I_{PE} + \delta I_S + \varepsilon I_T + \zeta I_R + \eta I_{PDR} + \theta I_{BS} + \iota I_J + \kappa I_C + \mu I_{IC} + \nu I_{DC}$$

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Node 8 IB : 60
Node 6 PIB : 40
Node 3 PIB : 65
Node 2 PIB : 44.5
Path THREE Selected : Final Influence Factor : 44.5
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C. Sample Output:

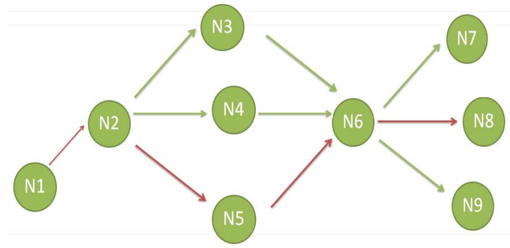

Fig. 2: Simulation output of sample network topology

D. Accuracy Measure

The accuracy of the system can be observed from the theoretical and experimental result. We have tested seven samples for all the network parameters range. The performances of the proposed system are listed here-

Subscript a, b, c, d, e, f for node number n= 4, 5, 6, 7, 8, 9 respectively.

Average accuracy, $A_{averge} = \sum A_i$

$$= \frac{A_{a1} + A_{a2} + A_{b1} + A_{b2} + A_{c1} + A_{c2} + A_{d1} + A_{d2} + A_{e1} + A_{e2} + A_{e3} + A_{e4} + A_{f2}}{14}$$

$$= \frac{100 + 99.99 + 99.99 + 100 + 99.99 + 100 + 99.99 + 100 + 100 + 100 + 99.99 + 100 + 100 + 99.98}{14}$$

= 99.995%

We can see that, the accuracy of the performance doesn't depend on the number of nodes. But if the number of node in a path increase the value of path influence behavior will also increase.

E. Simulation Result

a. Relationship between Device Class and Path Influence Behavior

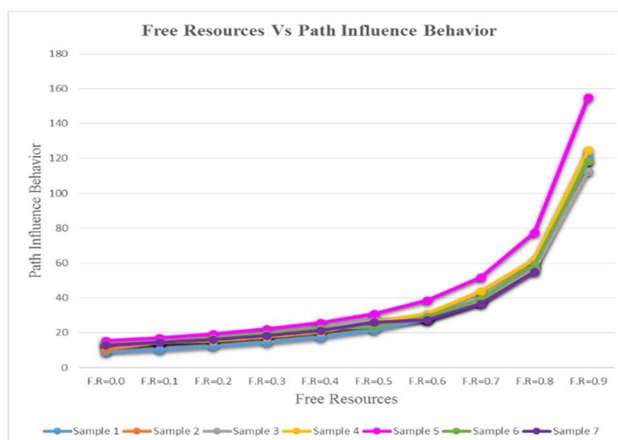

Fig.3: Device Class vs. Path Influence Behavior

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In Fig. 3, X-axis shows the Device Class [4; 20], where 4 indicates the less powerful device and 20 indicates the most powerful device and Y-axis shows the Path Influence Behavior.

Observations:

- From Fig. 3, we can see that increasing the value of Device Class will increase the value of path influence behavior which means that powerful device has the highest influence value and prefer for communication among device.
- The lower the value of Device Class, the lower the value of path influence behavior.
- The Path Influence Behavior value doesn't depend on the number of nodes, but depends on the value of Device Class.
- The lower the Device Class, the free resources play a significant role in the value of path influence behaviour.

b. Relationship between Free Resources and Path Influence Behavior:

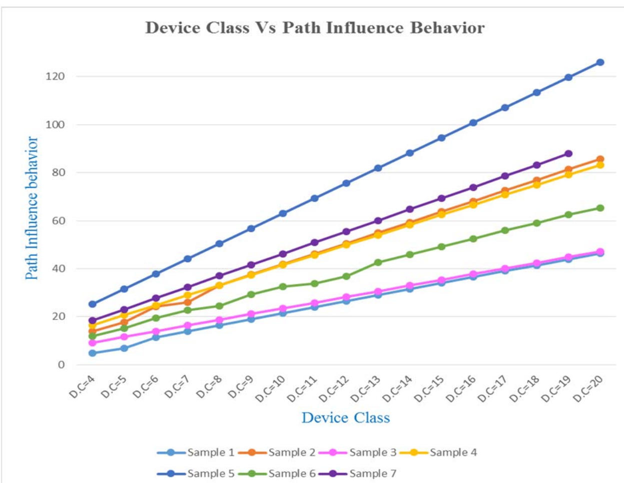

Fig. 4: Free Resources vs. Path Influence Behavior

In Fig. 4, X-axis shows the Free Resources [0.0; 0.9], where 0.0 means 100% resources are occupied and 0.9 means 100% resources are free and Y-axis shows the Path Influence Behavior.

Observation:

- From the figure, we can see that increasing the value of Free Resources will increase the value of path influence behavior that means device contains free resources to get chance first for communication.
- The lower the value of free resources, the lower the value of path influence behavior.
- The Path Influence Behavior value doesn't depend on the number of nodes but depends on the value of free resources.
- Here, we can see an exponential relationship between the Path influence behaviors and free resources.

From the range [0.6; 0.7] of free resources, the value of path influence behavior increases extremely fast.

Based on the figures and simulation result, the following conclusion can be drawn:

- The greater the value of Device Class the greater the possibility for the value of the Behavior to be with higher value. That means that more powerful device can perform well comparing low powerful device. For example, if any device has high processing power, RAM speed, battery life will show the high behavior value and get a chance than a low power device for communication.
- The greater the value of Free Resources the greater the possibility for the value of the Behavior to be with higher value. That means that the device which contains more free resources easily occupied for data communication.
- There is a linear relationship between Device Class and Path Influence Behavior which means that increasing the device class will increase the path influence value and may be capable of communication.
- There is an exponential relationship between Free Resources and Path Influence behavior which means that for any communication we need to increase the free resource value.

c. Comparison with Existing Algorithm

"Behavior of whole path" algorithm which is proposed in [1] is applicable for one topology contains 5 nodes. The proposed algorithm has removed this limitation. The proposed system is built to analyze any network topology for finding out an optimized path in order to node-to-node data communication.

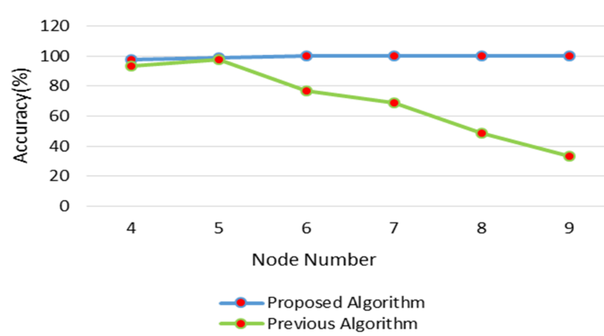

Fig. 5: Comparison of previous and proposed algorithm in respect of Node number

We have tested both previous [1] and proposed algorithm for 7 network topology samples contains several nodes. In Fig 5, X-axis shows the node number and Y-axis shows the accuracy of successful path and partner selection based on Path Influence Behavior. We can see that the accuracy of the previous algorithm is decreasing when we increase the number of nodes, but the accuracy of the proposed algorithm is near to constant that case.

V. CONCLUSION

In IoT network topology, path and partner selection for data communication is a very important and essential part. The proposed Path and Partner selection algorithm in Unstructured Resource Constrained Environment solved the path and partner selection problem when the destination node is more than one hop away from the source node in the hybrid flexible architecture. This algorithm can enable to discover the most suitable route for the need for a complete source-to-destination connection establishment. The proposed algorithm can also solve the contradiction when the Path influence behavior of two or more route is the same. Here, we examined seven samples including a variable number of node and evaluate the system by using a large set of data range. The performance is also measured by using summation and average calculation. In the end, we analyzed the relationship between Network parameters such as Device Class and Path Influence Behaviour from simulation result to validate the proposed algorithm.

VI. FUTURE WORK

The following enhancements can be further looked into:

- The Device Class and Free Resources parameter should be further researched and should increase the range.
- Should reduce the exponential time for decision making into logarithmic or linear time when a number of node are huge.
- Can introduce more network parameter, security mechanism and different priorities such as Emergency Priority which can classify the service type.

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