A Novel Min-Max Fuzzy Logic to Guarantee Reliable Data Delivery through Optimal Route in Cluster based Delay Tolerable IoT network

Synopsis-

Internet of things (IoT) and delay tolerant network (DTN) are emerging technologies that enables many real-time applications. Both IoT and DTN paradigms are integrated in order to utilize DTN based communication in IoT for many applications such as monitoring [1]. However, in DTN there is no end-to-end connection between source and destination which degrades the performance of data transmission [11]. In IoT networks, multipath routing was optimized with the support of particle multi-swarm optimization (PMSO) algorithm [2]. Here exchange of particle best message between sensor nodes increases packet flooding in the network. Multipath load balancing (MLB) routing process was designed for data transmission in wireless sensor network (WSN) based IoT [8]. In MLB, continuous selection of same shortest path leads to high packet loss due to dynamic mobility and energy consumption of nodes. Data aggregation was also concentrated in IoT with TDMA based MAC scheduling [10]. Transmission delay is high due to involvement of TDMA based transmission. In the presence of mobile sink virtual grid based dynamic route adjustment (VGDRA) algorithm was utilized for data transmission [9]. Data transmission through non-optimal route leads inefficient data transmission.

Trust based intelligent routing [7] was attempted to select trustworthy route with the help of artificial neural network (ANN). It shows that trust value alone is not able to select optimal routing path. For efficient data forwarding, connection status was determined by Naïve Bayes classifier in DTN enabled IoT [3]. Here RSSI and transmission rate were considered as attributes for Naïve Bayes classifier. In general, Naïve Bayes classifier works well when all attributes are mutually independent. Thus considering RSSI and transmission rate as attributes which are dependent each other leads to inefficient accuracy (i.e.) determined connection status is not accurate. Data transmission through non-optimal route is also a major problem in this work. An adaptive forwarding algorithm based on spray and wait protocol was proposed for reliable data

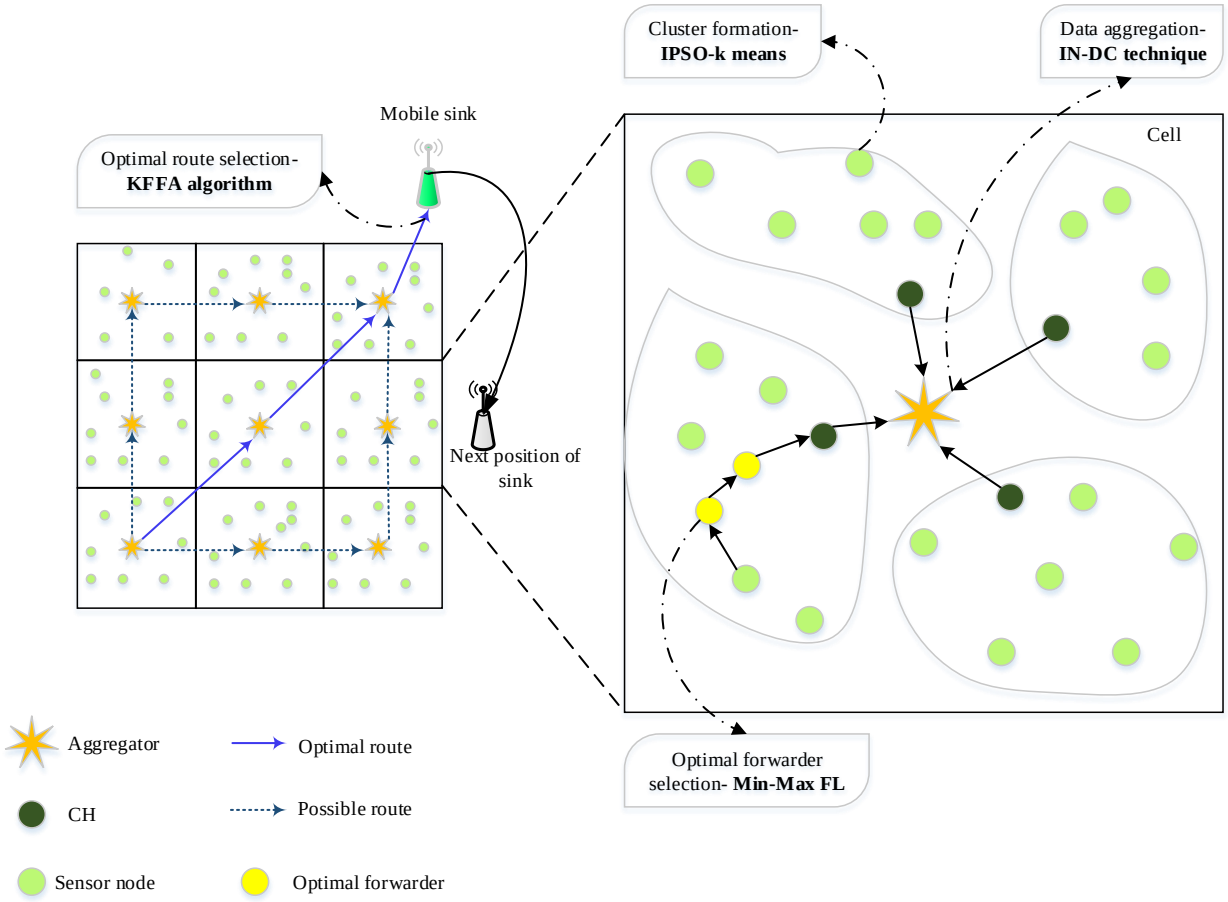
transmission in DTN [4]. Here delivery potential (DP) was computed based on encounter record (ER) in order to select optimal forwarder. However, the link status is varied with mobility of nodes. Thus selecting forwarder selection based on DP regardless current link status leads to ineffective data transmission. In fuzzy based system, optimal IoT device was selected based on storage capacity, waiting time, remaining energy, and security level [5]. Perhaps this method selects optimal IoT device, it consumes more time for forwarder selection since it executes 81 rules. Thus additional delay is introduced in data transmission. Delivery in DTN based IoT network was improved by utilizing RSSI information based distance computation [6]. This method increases packet flooding due to presence of spin phase which leads to large energy consumption and time consumption.

To resolve aforementioned problems this research work concentrates on improving delivery ratio and delivery delay. To improve data delivery we perform following processes: (i) cluster formation, (ii) optimal forwarder selection, (iii) data aggregation, and (iv) efficient routing. Initially the network is divided into multiple equal sized cells. In each cell, we deploy *Aggregators* at the center point of the cell. Aggregator is responsible for cluster formation as well as data aggregation. For cluster formation we introduces an **Improved Particle Swarm Optimization based K-means (IPSO-K means)** clustering algorithm. Here initial centroids for k-means algorithm are selected by IPSO algorithm based on centroid factor (distance, node degree, and centrality). Further, the formed clusters are managed by aggregators through cluster merging and splitting processes accordance with node density. In each cell, the sensed data from each sensor is forwarded to aggregator through optimal forwarder node. A novel **Minimum-Maximum Fuzzy Logic (Min-Max FL)** is proposed for optimal forwarder selection. Here *incremental factor* (based on remaining energy, RSSI, and link stability), *detrimental factor* (distance, and mobility), *variance factor* are considered in fuzzy logic. At aggregators the aggregated packets are categorized into emergency and non-emergency packets based on flag value. Non-emergency packets are compressed by **In-networking Dual Compression (IN-DC)** technique. Then aggregator waits for mobile sink arrival, after that it transmits the compressed data to mobile sink. Involvement of data compression minimizes the number of transmission which leads to higher delay. However, the emergency packets must be served with minimum delay which is not able to wait until mobile sink arrival. Thus when an emergency packet is identified by aggregator then that packet is transmitted to sink node immediately through optimal

route. The optimal path for data transmission is selected by **Knowledge based Firefly optimization Algorithm (KFFA)**. Here optimal route is selected from routing table based on delay and hopcount. Finally, our proposed work is evaluated in terms of following performance metrics,

- Delivery ratio
    - With respect to number of nodes
    - With respect to buffer size
- Delivery delay
    - With respect to number of nodes
    - With respect to buffer size
- Overhead ratio

Overall Architecture



Reference Explanation

Reference: 1

Title: Internet of Hybrid Opportunistic Things: A Novel Framework for Interconnecting IoTs and DTNs

Concept:

This paper proposes a novel framework to connect IoT with DTN. Here a hybrid opportunistic things framework based on IoT-cum-DTN is implemented to seamlessly utilize DTN based communication in IoT. The implementation is realized by considering following design principles: (i) transparent DTN connectivity, (ii) transparent IoT P2P connectivity, and (iii) DTN IoT interoperability.

Reference: 2

Title: Optimizing Multipath Routing With Guaranteed Fault Tolerance in Internet of Things

Concept:

In this paper, a bio-inspired particle multi-swarm optimization (PMSO) routing algorithm is introduced in IoT. Here PMSO algorithm is utilized to construct, recover, and selects k-disjoint paths to tolerate the failures. Coverage factor and sensor failure rate are considered in fault tolerance model. Further, energy level, hop count, and delay are considered for route selection through PSO algorithm. In this approach, the personal best messages are transmitted between nodes to improve the performance.

Problems:

- Exchange of pbest message between nodes increases packet flooding in the network.

Proposed solution:

- Our proposed work controls packet flooding through data aggregation dn optimal forwarder selection

Reference: 3

Title: Efficient data-forwarding method in delay-tolerant P2P networking for IoT services

Concept:

This paper deals with IoT network with multiple mobile sink nodes. For efficient data forwarding, delay tolerant capability is adopted in the network. Here the delay tolerant nodes (i.e.) gateways are tried to transmit data to sink nodes. All sensor nodes send their sensed data to gateways and gateway transmit aggregated data to mobile sink based on connection status. When a mobile sink node appears near to gateway, then it checks the connection between gateway and sink node. The connection status is determined by naïve Bayes classifier by using RSSI and transmission rate attributes.

Problems:

- Naïve Bayes classifier performs well when all attributes are mutually independent. However, the considered attributes RSSI and transmission rate are dependent each other. Thus the classification accuracy is low which leads to ineffectual data transmission.
- Data aggregation is not reliable since all nodes transmit their data through ineffectual route

Proposed Solution:

- In proposed work, optimal forwarder selection is performed by Min-Max FL based on multiple significant metrics
- Sensed data is transmitted to aggregator through optimal forwarder

Reference: 4

Title: Adaptive Forwarding Scheme for Bounded Time Constraint in Delay Tolerant Networks

Concept:

This paper introduces an adaptive forwarding algorithm based on spray and wait algorithm to improve the data transmission in DTN. In this adaptive algorithm, the number of

message copies and forwarding algorithm are dynamically adjusted according to user requirement and current service level. For this purpose it follows two phases as follows: analytical model and measurement model. In analytical model, number of message copies is transmitted to intermediate nodes by source node. Then the number of successfully delivered packets is updated in encounter record (ER). In measurement model, the delivery potential (DP) is computed based on ER record. Then relay node is selected based on DP.

Problems:

- Maintaining ER record at each node increases complexity since nodes move with dynamic mobility
- Data transmission is not efficient since link status changes over a time with respect to major parameters.

Proposed Solution:

- In our work routing table is maintained at aggregator nodes only
- Data transmission between nodes and aggregator is improved by min-max FL algorithm similarly data transmission between aggregator and sink node is performed by KFFA algorithm.

Reference: 5

Title: Implementation and performance evaluation of two fuzzy‐based systems for selection of IoT devices in opportunistic networks

Concept:

This paper introduces an algorithm for IoT device in opportunistic networks and DTNs. Two fuzzy systems are proposed in this paper for IoT device selection. In first fuzzy system Io device is selected based on storage capacity, waiting time, and remaining energy. Here twenty seven fuzzy rules are deployed for IoT selection. In second fuzzy system storage capacity, waiting time, remaining energy, and security level are considered for IoT device selection. In second fuzzy system eighty one rules are deployed for IoT device selection. Further, it is concluded that second fuzzy system outperforms well in IoT device selection.

Problems:

- Considering 81 rules for IoT device selection increases complexity
- Data delivery delay is increased since IoT device selection process consumes more time

Proposed Solution:

- Min-Max FL minimizes number of rules (8 rules only considered) through formulation of novel factors
- Transmission delay is minimized by reducing number of rules as well as optimal forwarder selection

Reference: 6

Title: Delay-tolerant sensing data delivery for IoT network by using signal strength information

Concept:

In this paper, location information of nodes is considered as major metric to improve routing efficiency. To this end a peer-to-peer DTN routing scheme is proposed. Here location information is determined by utilizing RSSI value instead of GPS and other localization services. Routing is performed in two phases as follows: (i) approach phase and (ii) spin phase. In approach phase single-copy forwarding is performed in non-target region. The relay node is selected based on distance value computed based on RSSI. In spin phase, multi-copy forwarding is performed within target contour.

Problems:

- It increases packet flooding at spin phase due to multi-copy forwarding
- Further, distance is varied over a time with mobility of node affects the relay node selection

Proposed Solution:

- Packet flooding is controlled by selecting optimal forwarder node by Min-Max FL algorithm and effective data aggregation

- Forwarder selection by Min-Max FL algorithm improves the efficiency of data transmission

Reference: 7

Title: Trust based Intelligent Routing Algorithm for Delay Tolerant Network using Artificial Neural Network

Concept:

To minimize security risk in DTN, trust based routing algorithm is proposed in this paper. Here trust value is computed by utilizing call data record (CDR) information. Artificial neural network (ANN) is used to calculate trust value for each node in the network. For trust value computation, connection time, frequency of calls, and total duration are considered. In each computation, the computed trust value is updated in CDR maintained at each node. Then the intermediate node is selected based on trust value.

Problems:

- Intermediate node selection based only on trust value minimizes transmission reliability
- Maintain CDR for all nodes other than neighbor nodes increases complexity

Proposed Solution:

- Forwarder selection by Min-Max FL considers multiple significant metrics

Reference: 8

Title: Multipath Load Balancing Routing for Internet of Things

Concept:

Multipath Load Balancing (MLB) routing process is designed for IoT based WSN that processed by using zigbee's AODV routing. MLB consists of LAYER_DESIGN and LOAD_DESIGN for effectively managing the different layers and balancing the load between nodes. LAYER_DESIGN is mainly concentrated to select the best next-hop for data forwarding. When the selected next-hop is failed to transmit the packet, it reselects the new next-hop for routing

process. Here, the beacon message is broadcasted for receiving the neighbor node information such as address, layer value, and network load. Based on beacon message, lowest network loading node is selected for forwarding data packet during a short period of time. LOAD_BALANCE is processed based on LOAD_DESIGN that estimates the network loading based on exponential weighted moving average formula

Problems:

- The continuous use of the nodes in the shortest path to the destination leads to fast energy consumption of those nodes which will ultimately lead to path failure.

Proposed Solution:

- Route selection is performed at each time by KFFA algorithm and forwarder selection is performed by Min-Max FL algorithm.

Reference: 9

Title: VGDRA: A Virtual Grid-Based Dynamic Routes Adjustment Scheme for Mobile Sink-Based Wireless Sensor Networks

Concept:

This paper deals with the mobile sink based wireless sensor network (WSN). Here the network is initially divided into multiple equal size grids and in each grid an optimal cell header is selected. The cell headers are responsible to track the location of mobile sink and to route the aggregated data. When sink is repositioned, then the nearest cell header informs about the sink movement to other cell headers. Upon received message, cell-headers adjusted their route for data transmission. In addition, cell header rotation is enabled for seamless data transmission.

Problems:

- Data transmission between cell-header and sink node is performed through non-optimal route which leads to large packet loss
- Cell header selection is not optimal since sensor node at center of the cell may not have higher energy at all time

Proposed Solution:

- Data transmission between aggregator and mobile sink is performed through optimal route selected by KFFA algorithm
- Optimal centroid nodes selected by IPSO algorithm is elected as cluster head (CH).

Reference: 10

Title: Energy-Optimal Data Aggregation and Dissemination for the Internet of Things

Concept:

In this paper, energy optimal routing, multiple sink aggregation, and dissemination are concentrated in IoT networks. In this paper, two models such as 1K model and nK model are introduced for data aggregation. The major aim of these models is to minimize energy consumption in the network. Time division multiple access (TDMA) based MAC scheduling is adapted for data transmission. The objective functions are formulated with total energy usage and min-max energy usage.

Problems:

- In this method number of transmissions is large since data aggregation is not efficient
- Emergency data transmission is critical due to TDMA scheduling based data transmission

Proposed Solution:

- Data aggregation by IN-DC technique minimizes number of transmissions
- Emergency data transmission by KFFA algorithm minimizes transmission delay

Reference: 11

Title: Movement-Aware Relay Selection for Delay-Tolerant Information Dissemination in Wildlife Tracking and Monitoring Applications

Concept:

IoT is integrated with DTN for monitoring applications in order to improve data transmission. This paper exploits the directional movement in path -unconstrained mobility. For

movement estimation, fuzzy path model with the influence of directional correlation is introduced. Here the correlation pattern of node mobility is considered to represent directional movement. Then based on mobility model, contact opportunities are mathematically analyzed to define delivery utility.

Problems:

- Increases computational complexity due to involvement of mathematical computation

Proposed Solution:

- Computational complexity is minimized due to simple computations

Reference: 12

Title: Controlled Replication Based Bubble Rap Routing Algorithm in Delay Tolerant Network

Concept:

DTNs are often called as opportunistic networks in which data transmission is allowed without end-to-end connection between source and destination. Due to lack of network connectivity, DTNs experiences large delay in data transmission. Thus it is necessary to optimize data transmission with minimum delay. In DTN, many data transmission strategies are proposed as follows: (i) direct delivery, (ii) Epidemic routing, (iii) spray and wait protocol, (iv) PROPHET protocol, and (v) MaxProb. In these protocols, majority of protocols are involves with packet flooding which degrades the network performance.

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