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OPTIMIZING PERFORMANCE OF COVERAGE DELAY IN WIRELESS MOBILE NETWORKS USING POWERED CLUSTER BASED ROUTING

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ABSTRACT

Delay/Disruption Tolerant Networking (DTN) permits the effective usage of numerous pathways and providers. The DTNs are different because they are not linked to each other. This means they don't have direct paths from one end to the other. Popular ad hoc routing protocols like Ad hoc on-demand distance vector (AODV) and dynamic source routing (DSR) are unable to construct routes in these difficult settings. Clustering is isolating the similar mobile nodes into numerous strewn groups, named as clusters. The transmission of data is done between various clusters in a cluster-head-to-cluster-head (CH-to-CH) fashion. In this research paper a novel clustering based approach is investigated for DTN, which is unique and non-trivial as the network links exist only temporarily, which makes it impossible to achieve end-to-end connection for data delivery. Therefore routing is based on nodal contact probability. Here, an exponentially weighted moving average (EWMA) method is applied, which is mainly for the online updating of nodal contact probability. Though the result gives an improved packet delivery ratio through which a high throughput and minimum energy consumption, this increases the burden on every CH. This study discusses an ideal clustering technique that uses two mechanisms: optimal cluster planning with routing awareness and optimum random relay with clustering awareness – to balance the strength of each cluster in a stochastic condition. As an outcome, optimal power consumption is attained with increased throughput and packet delivery ratio.

Keywords: *Delay Tolerant Network, Clustering, Coverage Constraints, Delay, Performance, Routing, Wireless Sensor Networks*

1. INTRODUCTION

In the DTN, communication linkages are momentary. End-to-end connections for data transmission are therefore hard to construct, although they are feasible in flat networks [1] because they are scalable, but in vast networks this appears to have failed. Clustering is seen to be a practical method for lowering network overhead and enhancing scalability. For mobile ad hoc networks, a variety of clustering methods have been suggested. However, none of these can be immediately adapted to DTN because they are made for networks with strong connections.

The cluster-based routing protocol and its power balancing technique for DTN are investigated in this study. Grouping mobile nodes as clusters with similar mobility patterns is the core concept. To accomplish effective and scalable routing on DTN, every node in the cluster can ex-

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changeably distribute their resources for load balancing and overhead reduction.

Due to poor network connection, which results in inconsistent details in mobile devices that could react differently, clustering in DTN becomes difficult. In order to create clusters and ensure their convergent nature as well the stability, it is therefore important to gather the relevant information. The on-line update of nodal contact probability uses a EWMA approach. Then, using three functions called Sync(), Leave(), and Join(), a distributed clustering algorithm may construct clusters and choose gateway nodes according to the calculation of nodal contact probabilities. The nodes used as gateways are those via which the CH sends data to the source [2]. The results demonstrate that it produces greater delivery ratios, reduced overhead, and higher packet delivery ratios, all of which contribute to higher throughput and less energy usage.

Each cluster head in particular has a load as a result of the data transfer being done CH-to-CH. By maximizing coverage duration and balancing the power usage across each cluster, one can reduce the load on CH. Here, we propose a stochastic scenario that consists of two mechanisms: optimum cluster planning that takes into account routing and optimal random relay that takes into account clustering [3]. These two mechanisms are applied for choosing a shortest routing path and to relay the traffic in the direction of the sink, as a whole, to balance the power consumption in each cluster so as to achieve an improved packet delivery ratio and throughput and minimized and balanced energy consumption. The investigation shows that the results are satisfactory in the power balancing approach than that with the usage of EWMA scheme.

The paper is divided into the following sections: The significant earlier research and efforts are presented in Section 2. Clustering is discussed in Section 3 along with two approaches that were used to compare it. The simulation settings and the results are explored in Section 4. The research study is concluded in Section 5.

2. RELATED WORK

Numerous articles from the past have discussed the clustering approach and its routing algorithms. A search is conducted across four important electronic data sources (EDS), including ACM, IEEE, WoS and Scopus, in order to choose the study's materials. The articles published between 2016 and 2022 are taken into consideration for selection. The main selection criteria include the keywords like wireless mobile networks, power balanced clustering, delay tolerant networks, coverage limits, and optimized clustering. These keywords are used in conjunction with Boolean operators like "AND" and "OR" to create a search query that then obtains the desired document from the sources. Additionally, manual inquiry is used to examine the collected documents' quality using content analysis. Only a few articles with significant efforts towards the power balanced clustering approach is accounted. Mobile nodes may receive inconsistent information in the DTMN, which causes them to respond indifferently. As a result, it becomes challenging to gather the data required to create clusters and guarantee their convergent growth and stability.

The importance and promising applications of WSN is deeply investigated [4, 5]. In one of the previous studies [6], the main goal was to achieve the simplicity of the DTN architecture and focused on the end-to-end delay network protocol. Investigations are made into the routing protocols that target DTN and the degree of its adaption. The outcome demonstrated a deployment and growth approach that was simpler while maintaining the architecture's simplicity [7,8].The suggested study is motivated by a power balancing strategy that was started [9], to improve the operational efficiency of the clustered wireless sensing networks. With the aim of reaching less connected mobile networks and achieving a better degree of success for data transmission, another study on improving the efficiency of the wireless mobile networking was discovered [10]. Five distinct opportunistic forwarding techniques that vary in overhead, success rate, and the level of neighbor information need were compared. As a result, there is a fair trade-off between resource overhead and performance, and data delivery success is increased [11].

One of the study [12] is elaborated the significance of clustering algorithm in delay-constraint networks. In further research, a clustering algorithm for achieving energy efficiency is designed, compared against low-energy adaptive clustering hierarchy (LEACH) which is a conventional protocol and proved its better performance [13]. An updated clustering with sleep scheduling algorithm [14] demonstrated its competence in reducing delay, increasing life time and throughput. Hierarchical clustering is used to reduce energy consumption of WSN. A LEACH based protocol is developed to handle energy consumption through forming clusters in hierarchical fashion [15].

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The routing algorithms which used multi-ring shaped infrastructure virtually in order to announce the mobile sink was exercised [16]. For heterogeneous WSN, the Reliable Cluster-based Energy-aware Routing (RCER) protocol [17] is presented, which increases network lifetime and lowers routing costs.

The proposed RCER protocol employs energy-differentiated nodes and is divided into two main steps: first, the network field is clustered geographically to increase network energy efficiency, and second, RCER seeks the best routing to enhance next-hop participation by considering balanced Round Trip Time (RTT), hop-count and residual-energy as the predominant parameters into account. To improve the QoS parameters, a Three-Tier Cluster-Based Routing Protocol for Mobile WSN is established [18]. In a wide range of environmental and civil surveillance applications, the proposed protocol proved largely suitable.

An energy efficient unequal clustering routing (EEUCR) is employed to improve the quality of service (QoS) measures of WSN [19]. The fuzzy logic-enhanced unequal clustering approach is intended to balance the energy limitations of WSN [20, 21]. The results reveal that the suggested protocol outperforms LEACH by lifetime improvements of 57.75%. Further, the unequal clustering is applied over the delay constraint networks of IoT applications [22]. Similarly an energy efficient clustering algorithm which works on gateway over precision agriculture is implemented [23]. The way to stabilize the performance of unequal cluster is described [24]. An intelligent clustering based routing scheme started to evolve through incorporating machine learning approaches together [25].

2.1 Research Objectives

The research goal of the work is to optimizing the performance of DTN through clustering based approach. The objectives are as follows:

1. To reduce the delay of transmission considering the characteristics of DTN
2. To increase the throughput by allowing cluster based routing
3. To improve the overall energy consumption

In order to attain the above-mentioned objectives, distributed powered clustering is proposed. The necessary details including the challenges of DTN, prominent elements and mathematical model of proposed design are discussed in the following section.

3. DISTRIBUTED POWERED CLUSTERING ALGORITHM

The clustering algorithm helps in achieving promising performance through effective routing. However the characteristics of the DTN influence its performance. To overcome the issues distributed version of power balanced clustering is proposed here.

3.1 Challenges in DTN

The proposed clustering algorithm for DTN undergoes the following method. First, each node learns direct contact probabilities to other nodes. It is not necessary that a node stores contact information of all other nodes in network. Second, a node decides to join or leave a cluster grounded on its contact chances to other members of that cluster. Since our goal is to combine together all nodes that have significant paired contact probability, a node only joins a cluster if its pair-wise interaction possibilities to all its neighbors exceed a threshold. If a node's connectivity probabilities with particular cluster members fall below, it departs the cluster. Once clusters are constructed, gateway nodes for inter-cluster communications are identified. Two clusters communicate primarily through gateways. There are certain problems that are faced in clustering. They are as follows:

- Partial clusters: Many unexpected clusters may arise as a result of incorrect information in the assessment of contact probability and the irregular arrangement of meetings among mobile nodes.
- Incompatible cluster membership and gateway selection: The problem of incompatibility occurs in both, cluster membership and gateway selection. If a node leaves a current cluster C and joins a new cluster, given the network has low connectivity, other members of C are not timely informed about the transform and hence it is falsely assumed that the node still remains in C. Two nodes in the same cluster may have two different gateways to another cluster. Or a gateway node might have left the cluster C and the cluster C might not be informed about the sudden transform.

3.2 Prominent Design Elements

A node with a very low nodal contact probability may appear as the cluster member of another node. The mobility pattern of a node may transform from time to time.

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Pair-wise contact probability has been widely used as a routing parameter in opportunistic networks. It is being used in this algorithm. Getting this parameter in a suitable format, however, is a huge challenge in DTN. The nave's method would be to keep track of every single meeting ever held. While this method is robust, it is inefficient in terms of storage and slow to respond to shifts in how people move around. For this reason, we use a method known as the exponentially weighted moving average (EWMA), which is both easy to implement and very accurate. In this method weighting factors decreases exponentially. The weighting for each older data point decreases exponentially, giving much more importance to recent observations while still not discarding older observations.

As its local information, a node keeps its ID, cluster ID, cluster table, and gateway table. There are four fields in the cluster table: Node ID, Contact Probability, Cluster ID, and Time Stamp. Every value in the table represents a node that has ever been met by a node. It is noted that the updating might not necessary be always correct/ accurate.

A node maintains its gateway information in the gateway table, with four fields: Cluster ID, Gateway, Contact Probability, and Time Stamp. The Cluster ID field contains the list of clusters known by a particular node. For each cluster, e.g., Cluster C, the Gateway field includes the ID of the gateway, while the Contact Probability field indicates the highest contact probability between the gateway and any node in Cluster C.

The delivery probability indicates the likelihood that a node can deliver data messages to the sink. The delivery probability of a node is updated as given in equation (1).

$$\xi_i = \begin{cases} (1-\alpha)[\xi_i] + \alpha\xi_k, & \textit{Transmission} \\ (1-\alpha)[\xi_i], & \textit{Timeout} \end{cases} \quad (1)$$

Where, ξi is the delivery probability of a node before it is updated, αξi is the delivery probability of a neighbor’s node and α is a constant employed to keep partial memory of historic status.

The algorithm is incident-driven, where the key part lies in the meeting event between any pair of nodes. A set of functions used in the algorithm are as follows:

- Synchronization:
  When two nodes in a cluster meet and both are verified as nodes in the cluster, the Sync() procedure is initiated. The two local tables can be shared and kept in sync. Because each node learns the network settings independently, there must be some way to bring them into sync. Any discrepancies can be "improved" upon by using the Timestamp column to "better" the network's knowledge.
- Leave:
  The node with a low level of stability is forced to leave the cluster. A node's stability is described as its lowest possibility of having contact with others in the cluster. It represents the likelihood that the node will be removed from the cluster owing to a weak contact probability. Following that, the node empties its gateway data and reset its cluster ID.
- Join:
  The Join() method is used to consolidate two existing clusters into one or to add a new node to the "perfect" one cluster. If a node verifies that it is a member of every other node in the target cluster, it will join that cluster. The new cluster will significantly increase its reliability. It will take the gateway database from another node in the cluster and modify its cluster ID when accessing a new cluster. There are three incidents here. They are as follows:
  a) Slot timeout incident:
     At the completion of each time slot, a Slot-Timeout event is generated, activating the practice of updating the connection probabilities using the EWMA approach. Following the update of the contact capability, the Gateway Update() work is executed to modify the gateway counter.
  b) Incident meeting with a node:
     A Meet-A-Node event is initiated after receiving a Hello message (an exchange between two meeting nodes). If both nodes are the same in the cluster, then the relationship check function is called to confirm that they are still competent to remain in the same cluster.
  c) Obsolete gateway incident:
     Cluster Based Routing is on-demand routing where the nodes are categorized into clusters. In cluster routing, routing is done using source routing. But for this, route reduction is used. When a node receives a response from a source destination, it tries to find the farthest node in the route that is its neighbor. With this principle, the route between source and destination can be shortened.

The power-balanced approach is to directly optimize reach times by considering the

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interaction between clustering and routing. Minimizing the total energy consumption is not the same as minimizing the coverage time, since the first criterion does not guarantee balanced energy consumption in different cluster heads. By switching the load from an overpowered to an underpowered cluster node, the coverage time can be minimized, even if the total power consumption is not necessarily minimal.

4. RESULTS AND DISCUSSION

This section is attempted to justify the benefits of power balanced clustering approach over EWMA clustering. The effectiveness of the same is also investigated with evaluation parameters like packet delivery ratio, throughput and energy consumption.

4.1 Simulation Platform

The network simulator NS-2 is used to expose the performance of the proposed power balanced clustering. The discrete events network simulator Ns2 is regarded as having been created across a number of prior research projects and awards. It has to do with the ongoing and ongoing active utilizations. The scripting environment in Ns2 is OTcl, and some further Ns2 modules have been written in C++. The simulation parameters used in this analysis are tabulated below as Table 1. In addition to interactive buttons used for procedures like selection, printing, zooming, and panning display options, Xgraph offers a wide range of capabilities using an x-y data plotter. It gets used to control the size of infinite data sets with a finite amount of data records and is able of plotting data from multiple numbers of files in the same graph. In contrast with deterministic models, which always produce the same outputs no matter what data is fed into them, stochastic models exhibit data and forecast outcomes that allow for a range of unpredictability or irrationality.

A stochastic case is analogous to a deterministic process, instead of dealing with only one possible reality of how the process might evolve over time. This means that even if the initial conditions are known, there are many possibilities to which the process can go; but some paths may be more likely and others less likely.

Table 1: Simulation Parameters

Network Type	Mobile
Connection Pattern	Random
Packet Size	512 bytes
Threshold Value	0.6
Number of Nodes	150
Transmission Distance	150 m
Frequency	9 MHZ
Bandwidth & MAC Data Rate	2 MBPS
Ideal Power	0.2 W
Recovery Power	0.6 W
Transmit Power	1.0 W
Data Traffic Type	CBR
Energy Model	Battery

In this process, the location of the nodes is not available ahead of time. It considers an area with uniformly scattered nodes. This stochastic case has two mechanisms by which coverage time is minimized and power is balanced. They are;

a) Optimal cluster planning with routing in mind
Routing-aware optimal cluster planning is a cluster approach that considers the shortest transitions between CH routes. It provides thoughtful maximum coverage time, which is solved using generalized geometric programming techniques.

b) Cluster-wise optimal random relay
Cluster-aware optimal cluster scheduling relays traffic on any neighboring uplink in the direction of the sink. The optimal way indicates rebroadcasting the ID when a relay selection failure occurs. This routing tactic ensures load-balanced clustering. We compare our EWMA scheme and the power balancing approach in clustering. The obtained results

show a reduction in the energy consumption of individual nodes, since they only have to communicate with their respective CHs and over relatively short distances.

In this work, the EWMA scheme is compared with a power-balanced approach. The study shows that the results of the power balancing approach are more satisfactory than using the EWMA scheme.

4.2. Evaluation Parameters

The significant parameters to chosen to showcase the performance of the proposed clustering is discussed below.

4.2.1 Packets Received

Packets are sent from the source to the target node. The amount of packets that make it from the origin to the destination without being dropped is referred to as received packets.

4.2.2 Throughput

The throughput of a network is measured as the packets-per-second rate. Throughput, also known as network throughput, is the average rate at which data is transmitted and received in a communication network. This information could travel along a specific path in the network, either physically or virtually.

4.2.3 Energy Consumption

In determining the total amount of energy that is used by the network, the energy consumed by each node during the sending of packets is factored in and accounted as energy consumption.

4.2.4 Packet Delivery Ratio

The packet delivery ratio is determined by multiplying the ratio of the number of packets gained to the total amount of packets delivered by hundred.

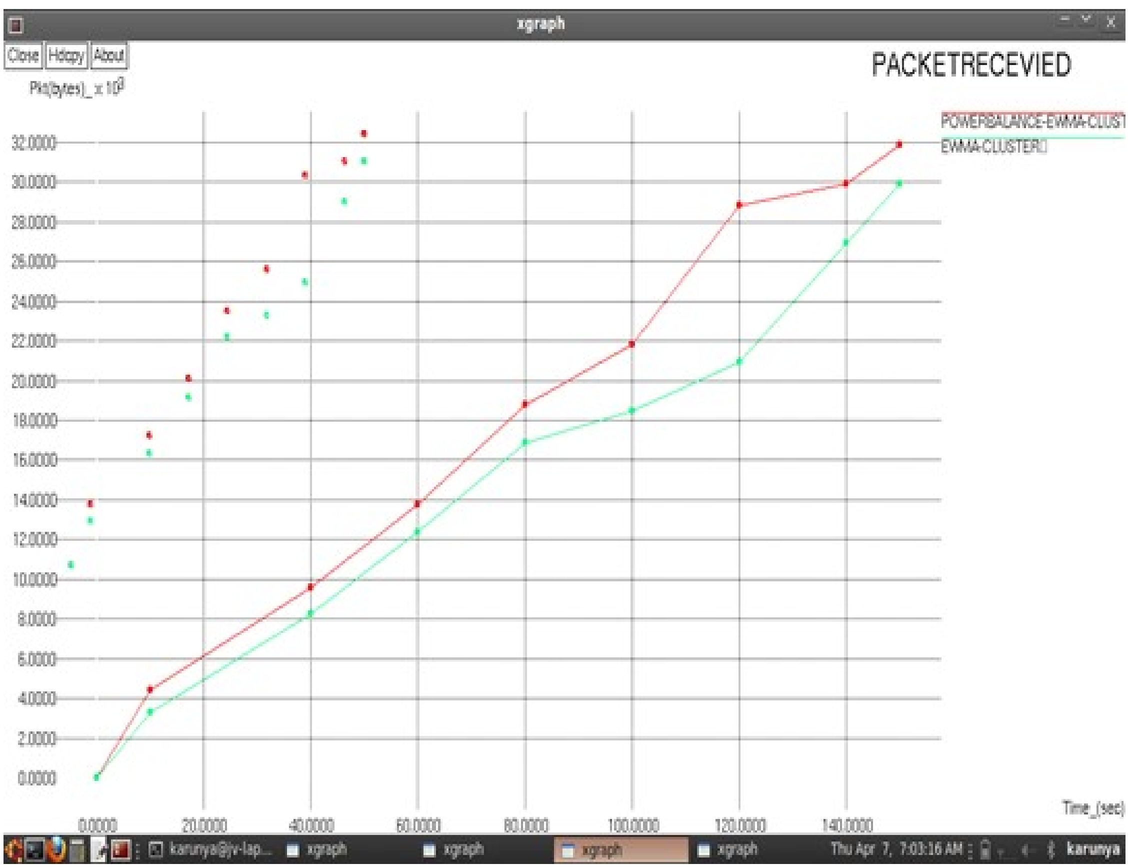

Figure 1: Comparative Analysis Of Packets Received

The y-axis represents the amount of packet received in bytes, while the x-axis represents the time in seconds. When comparing to the EWMA technique, the total amount of packets retrieved is 19.8 percent greater when the power balanced technology is employed.

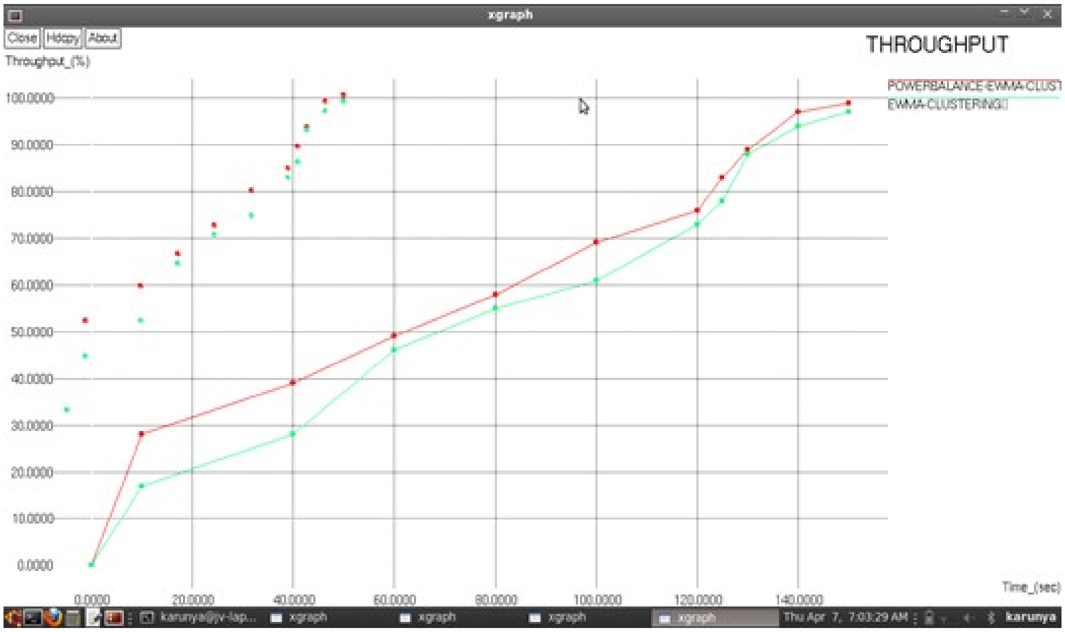

Figure 2: Relative Analysis Of Throughput

The y-axis represents throughput as a percentage, whereas the x-axis represents time in seconds. It has been shown that compared to the EWMA scheme, the average throughput improves by 15.1% when using the power balancing method.

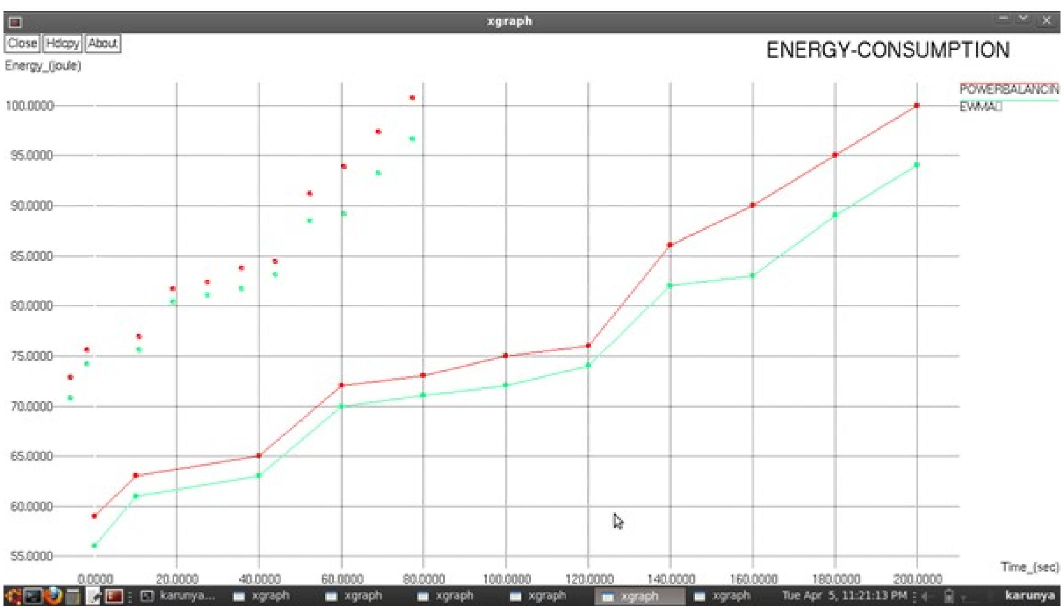

Figure 3: Comparative Exploration Of Energy Consumption

Total energy consumption is analyzed and compared between the EWMA and power balanced methods. The x-axis represents time in seconds, while the y-axis represents energy in joules. Compared to the EWMA, the power balanced method results in a 3.4% increase in overall energy consumption. By taking a power-balanced strategy, significant amounts of resources can be conserved.

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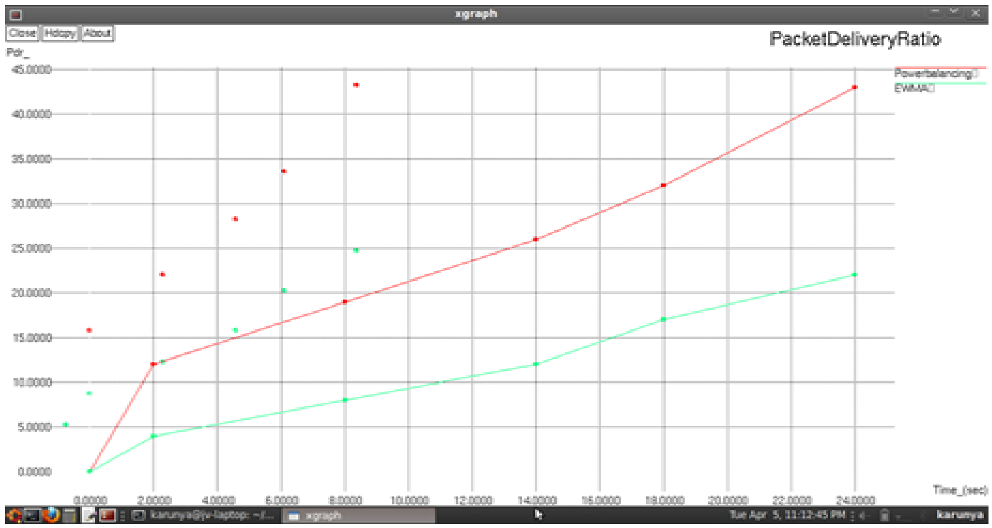

Figure 4: Performance Assessment Of Packet Delivery Ratio

The x-axis represents seconds, while the y-axis represents the number of bytes of packets received. The percentage difference of packet delivery ratio between EWMA and the power balance approach is 85.6%. The careful assessment of nodal probability ensures this approach to maintain its performance irrespective of various choices of simulation parameters.

5. CONCLUSION

In general terms, the EWMA is a statistics for tracking a process that generates the data in a way that diminishes the weight of the data as it is further removed in time. Using an approach termed power balanced EWMA through cluster planning and relay, with an aim to address the energy efficiency and hot spot problems of DTN in this paper. The proposed approach is examined against EWMA. The result show that the power balanced EWMA increases the received packets as 19.8%, throughput as 15.1%, packet delivery ratio as 85.6%, and energy consumption as 3.4% greater than EWMA.

The applicability of machine learning algorithms in supporting coverage constraints of wireless network is our future concern.

AUTHORS CONTRIBUTION

All authors are equally contributed.

CONFLICTS OF INTEREST

The authors declare that there is no conflict of interest regarding the publication of this paper.

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