# Load Balancing and Interference Delay Aware Routing in IoT Aware Wireless Mesh Networks

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## Abstract

The Internet of Things (IoT) enables embedded devices to connect to the internet either through IP or the web in a physical environment. The increase in performance of wireless access services, adaptive load balancing, and interference routing metric becomes the key challenges in Wireless Mesh Networks (WMN). However, in the case of IoT over WMN, a large number of users generate abundant net flows, which can result in network traffic jam. Therefore, in this paper, we propose a Load Balancing and Interference Delay Aware routing metric algorithm to efficiently address the issues present in the current work. The proposed scheme efficiently utilizes the available mesh station queue information and the number of mesh stations suffering from channel interference in the available path. The simulations results show that the proposed scheme performed superior to the existing routing metrics present in the current literature for similar purposes.

**Keywords:** Internet of things, Load balancing, Interference delay aware, Wireless mesh networks, routing metrics, Internet protocol

## 1 Introduction

The Internet of Things (IoT) is progressively growing into different fields such as smart e-health services, smart homes, etc. In order to integrate the IoT services into different fields, requires extensive modification in the existing architecture of each technology. For example, Bluetooth, and WirelessHRT does not support IP functionalities directly, therefore, a gateway is required to translate the information to an IP network [1]. Similarly, Wireless Mesh Network (WMN) is a new and hot area of research providing fastest end to end connectivity among two physical objects connected to the internet [2]. Therefore, using the WMN services for IoT requires extensive analysis of the existing architecture in the context of routing data among the mesh stations (MSTA), selecting the best link among available networks, etc. In general, the WMN provides a two layer wireless architecture. In the first layer, the mesh routers form an ad-hoc wireless network using self-configuration functionality. Similarly, mesh gateways are selected from the mesh routers to communications with the internet. In the second level, the MSTA gets connected to ad-hoc network forms in the first level. WMN provides many functionalities such as low-cost deployment, efficient communication model, self-healing, etc. In addition, the MSTAS does not suffer from high energy consumption and processing power while communicating with the mesh network. The ubiquitous communication significantly increases the throughput in a WMN environment [3]. Similarly, the infrastructure functionality significantly reduces the complexity of underlying protocols. One of the key advantages of WMN is providing of internet access in the developing areas where the wired network is not available. Moreover, the applications of WMN can be found in many areas such as broadband house networking, community networking, healthcare systems, etc. The WMN is widely researched in near past. However, there are still many challenges exists in its current architecture. For example, WMN always consists of many nodes and thus scheduling of transmission at the Medium Access Control (MAC) is a challenging task. An efficient scheduling mechanism significantly increases the throughput of WMN. Similarly, in near future, many nodes will communicate with each other in an IoT scenario as shown in Figure 1. Therefore, dealing with a huge number of nodes may cause interference and overloading on different links in a WMN scenario [4].

The recent literature consists of various schemes to efficiently balance the flow of data on a routing path in WMN. However, load balancing and minimizing delay are some of the subproblems that need to be addressed before designing a scheduling mechanism [5]. The efficient routing among the MSTA and routers can be achieved by designing a routing metric which can incorporate various parameter affecting the performance of a routing algorithm. The architecture of

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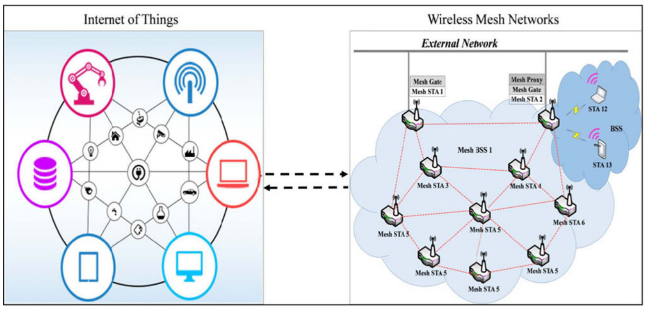


**Figure 1.** Network architecture of 802.11s WMN LANs

WMN is entirely different from the existing technologies such as Wireless Local Area Network (WLAN), etc. Wireless Sensor Network (WSN), etc [6]. In addition, WSN is widely used in many fields such smart homes, smart industry, hospitals, etc. [7]. Therefore, employing the existing routing algorithms in WMN can produce various problems such as high delay [8], less throughput, etc. [9].

Recently, researchers proposed various schemes to address the aforementioned problems. The IEEE established various groups to revise the protocol design of various IEEE 802.XX standards. For example IEEE 802.11, 802.15, and 802.16 have established various sub-groups to design new standards for WMN [10-12]. However, the WMN technology is not yet fully operational in the existing infrastructure. The integration of WMN with these technologies will still take the time to fully operational. Similarly, researchers also trying to resolve the routing and scheduling issues in the existing WMN environment. For example, several routing metrics have proposed to efficiently route the data in a WMNs environment. For instance, a quality aware routing metric i.e. Expected Transmission count (ETX) is proposed to improve the throughput in a WMN environment [13]. However, the ETX does not perform well in an environment where channel variation is high. The ETX uses mean loss ratio to decide the optimal routing path. However, mean loss ratio performs decision on the basis of average packet loss and thus perform poorly in burst loss conditions. Similarly, other routing metrics such as modified ETX (mETX), Effective Number of Transmission (ENT), etc. incorporate extra overhead in achieving high network capacity. Moreover, those routing metrics does not consider the load in the network. Thus, highly affects from the imbalance network flows and creating congestion on different links.

The routing protocols in WMN select an optimal path through route discovery mechanisms and are also rarely used to improve the quality of the selected paths. A routing metric essentially provides a snapshot of the optimal path available in the network at a particular time. Thus, a path initially selected by a routing protocol remains connected unless the path breaks or the flow of traffic comes to an end. This implies that the paths selected by routing protocols are also susceptible to the traffic load conditions, interference and noise levels. Different from classical ad hoc networks, most applications of WMNs are broadband services with heterogeneous QoS requirements. Thus, in addition to End-to-End (E2E) transmission delay and fairness, other performance metrics, such as delay, jitter, aggregate and per-node throughput, and packet loss ratios, must be considered while designing of communication protocols for WMNs.

In order to address the aforementioned challenges, we propose a load and interference-aware routing metric. The proposed routing metric uses two different components to balance the load and reduce the interference among different links on a path. The first component is called the cumulative load balancing which captures the traffic load transmission time from all neighbors MSTAs in a particular path and the second component is the interference delay aware that captures the effects of interference by the traffic load transmission time of all the interfering neighbors. The proposed routing metric is compared with the WCETT metric in terms of end-to-end delay, hop count etc. The results show much better performance over the WCETT. Our contribution in literature is summarized below:

1. In IoT over WMN environment, a Load Balancing and Interference Delay Aware routing metric algorithm is proposed to decrease the generation of abundant net flows to avoid network traffic jam.

2. The proposed scheme efficiently utilizes the available mesh station queue information and the number of mesh stations that suffers from channel interference in the available path. This increases the network energy efficiency by managing the interference delay.

The rest of this paper is structured as follows. Section 2 provides an in-depth analysis of the related works. Section 3 presents our proposed load balancing and interference algorithm for IEEE 802.11s networks. Simulation results are given in section 4 and finally, conclusions are combined in section 5.

## 2 Related Work

The WMN is mainly based on the architecture of IEEE 802.11s. The architecture of IEEE 802.11s is shown in Figure 1 [14]. An MSTA is an 802.11 entity that can support Wireless Local Area Network (WLAN) mesh services. A proxy mesh gate is a logical point where MAC Service Data Unit (MSDUs) enter or exit. Moreover, a WMN forms a connection with another WMN using traditional IEEE 802.11 or a non-IEEE 802.11 network approach [15]. A mesh Basic Service Set (BSS) is an IEEE 802.11 LAN consisting of autonomous STAs. Inside the mesh BSS, all STAs establish peer-to-peer wireless links and transfer messages mutually. Further, using the multi-hop capability, messages can be transferred between STAs that are not in direct communication with each other over a single instance of the wireless medium. From the data delivery point of view, it appears as if all STAs in a mesh BSS are directly connected to the MAC layer, even if the STAs are not within the range of each other. The multi-hop capability enhances the range of the STAs and provides benefits during wireless LAN deployments [16].

WMNs are quite different from traditional networks in many aspects. However, our main focus in this paper is the analysis of routing algorithms and metrics. The recent research consists of various routing approaches based on minimum hop count [17]. Because these strategies consider the quality of link for forwarding data. Moreover, minimum hop count based approaches select a route based on signal strength, frame rate, etc. reveals that these strategies depend on the physical layer being used. The channel variations are very high and a mesh client needs several parameters adjustment before selecting a route for data transfer. Similarly, the error detection techniques available in the current wireless technologies such as 802.11 and 802.15 are not enough to handle the error rate which ultimately slows down the frame transmission rate. In order to address the frame transmission failure, De Couto et. al. proposed ETX in [18]. The ETX performs retransmission of frames to successfully transfer it over a radio link. Whenever an MSTA wants to communicate with its neighbor node, it calculates the Frame loss ratio ($P_f$). Similarly, the MSTA compute the frame loss ratio ($P_r$) in the reverse direction from each neighbor. In general, the MSTA broadcast the packets that are not transmitted on any link. Finally, the ETX computes the ETX count $(1-(1-p_f)(1-p_r))$ to each neighbor and select the one with smallest ETX value.

A routing metric based on the average measured roundtrip time (RTT) has been proposed in [19]. The RTT periodically pings its neighbors using unicast probe requests. Finally, the path with smaller RTTs is selected for communications. The RTT is load-sensitive and, therefore, it performs poorly because of itself interference. The ETX does not consider the bandwidth of a link and therefore cannot address the load balancing in a WMN environment. A routing metric called "bandwidth-adjusted ETX" is proposed in [20]. However, simply multiplying the bandwidth with ETX is not a solution for fixing load balancing problem. Because bandwidth calculation of a link is a very complex task. Therefore, obtaining the exact value of bandwidth can solve the problem of load balancing up to some extent. Thus, incorrect bandwidth calculation can lead to choosing an inappropriate link. However, several techniques are available in the literature to estimate a significant value of bandwidth.

A technique used to measure the bandwidth value of a link is proposed in [21]. The proposed mechanism employed a probing mechanism based on transmitting a pair of packets to its neighbor nodes upon receiving the pairs of packets, the receiver computes the time difference between the two packets and sends it back to the sender. Finally, the sender calculates the bandwidth of the link by dividing the packet by the time sent by the receiver after a minimum of 10 samples. However, such estimation of bandwidth has several factors which directly affect the packet transmission time. A routing metric called Weighted Cumulative Expected Transmission Time (WCETT) has been proposed in [20]. The WCETT combine the individual link weights into a single path metric to address the interference among the links using the same channel. However, the WCETT have still some issues such as (1) not consider the link load explicitly and (2) poor performance in minimizing intra-flow interferences. Moreover, WCETT provides support for multi-radio but it does not consider a number of links operating on the same channel. Furthermore, WCETT is not isotonic and, therefore, it does not preserve the weights of two paths. Therefore, implanting the WCETT routing metric can lead to above problems in a WMN scenario. Moreover, the above literature reveals that using the existing routing metrics for data transfer in an IoT aware WMN does not give significant solutions and therefore, a need for an IoT-aware routing protocol is need of the day.

## 3 Proposed Solution

Our Load Balancing Interference Delay Aware routing (LBIDA) technique is the constituent of two major modules; a) Load Balancing Module (LBM) b) Interference Delay Aware Module (IDAM). Integrating these modules come up with a routing mechanism with load balancing and interference delay aware features. In addition, the proposed routing algorithm helps in finding the best and optimal path in an IoT-aware environment for efficiently transferring data over less congested paths. The terms that are used in the equations and their description is shown in Table 1.

**Table 1.** Description of Terms used in Equations

| Terms | Description |
|---|---|
| $T_{CCA}$ | Channel Clear Assessment Time |
| $T_{air\_prop}$ | Air Propagation Time |
| $CW_{min}$ | Minimum Contention Window |
| $CW_{max}$ | Maximum Contention Window |
| $T_{suc}$ | Success Time |
| $T_{col}$ | Collision Time |
| $T_{turnaround}$ | Turnaround Time |
| $R_xRF_{delay}$ | Delay in receiving the signal |
| $R_xPLCP_{delay}$ | Delay in physical layer convergence protocol |
| $MAC_{proc\_delay}$ | Delay in processing at MAC layer |

### 3.1 Load Balancing Module

Considering congestion level as parameter in forwarding node selection seems a wise decision. So, for characterizing the congestion level, $L_{con}^{j}$ at node $i$, we are picking the information of node's current buffer status $B_f^j(t_1)$, which shows the free space in the buffer at the time $t$ to better accommodate the incoming packet. If $B_s^j(t_0)$ is node $j$'s buffer size at time $t_0$ (total buffer capacity) and $B_s^j(t_1)$ is node $j$'s buffer size at $t_1$ then $B_f^j(t_1) = B_s^j(t_0) - B_s^j(t_1)$. This case is for homogenous networks to setup the justice in designating the node as optimal forwarding node. In the case of heterogeneity especially with respect to buffer memory size, buffer capacity ratio is preferred i.e. ratio of occupied buffer capacity to the total buffer capacity. So the equation will be

$$B_c^j(t_1) = \frac{B_s^j(t_1)}{B_s^j(t_0)} \quad \textbf{(1)}$$

For fair comparison of workload on neighbors of node $i$, the ratio of work load at node $j$, $B_c^j(t_1)$ to the total work load of all the neighbours of node $i$, $N_i$ i.e. $\sum_{k=1}^{n} N_i[B_c^k(t_1)]$. Thus, the congestion level, $L_{con}^{j}$ at node $j$ is

$$L_{con}^{j} = \left(1 - \frac{B_c^j(t_1)}{\sum_{k=1}^{n} N_i[B_c^k(t_1)]}\right) \quad \textbf{(2)}$$

where $j = 1, 2, \ldots, n$ and $j \neq k$

Since, based on controlling the congestion at the node, we are balancing the load on the network. So, the congestion level at any potential forwarding node is for handling the load balancing at the node. Hence,

$$LBM_j = L_{con}^{j} \quad \textbf{(3)}$$

### 3.2 Interference Delay Aware Module

Medium remains busy due to two major activities. One is productive and the other is unproductive. For the former case, we receive the output that results in increasing the network throughput. The Later case is just with no output but an effort to keep the system working against various hindrances like collision etc. Hence, IDAM makes an interference delay aware decision based on the comparison of severity at competing links that is the ratio between the packet size and the time to transmit it over a medium of actual bandwidth. This time, also contain that time of consumption for unproductivity activities $(T_{con\_ua})$. If the packet size is 'S' and $T_{con\_ua}$ is given as below:

$$T_{con\_ua} = [1 - (\frac{T_{wait} + T_{col} + T_{backoff}}{T_{wait} + T_{col} + T_{backoff} + T_{suc}})] \times Bandwidth \quad \textbf{(4)}$$

Then the value of IDAM at link *ij* becomes

$$IDAM_{ij} = \frac{s}{T_{con\_ua}} \quad \textbf{(5)}$$

The detailed calculation of the time consumption for the unproductivity activities $(T_{con\_ua})$ is given in the subsequent section.

#### 3.2.1 Calculation of $(T_{con\_ua})$

Time consumption for the unproductivity activities is comprising of four states namely wait, backoff, success, and collision as are given in Equation no. 4 that are actually the constituents of Distributed Coordination Function (DCF). The by-parts calculation of $T_{con\_ua}$ is given below. Let the time spent for wait is $T_{wait}$ that is calculated as follows.

$$T_{wait} = T_{data} + T_{SIFS} + T_{DIFS} \quad \textbf{(6)}$$

$T_{backoff}$ is backoff time and backoff is a mechanism that is used in order to avoid collisions. Collision is avoided by requiring the node to wait for a time that is called Backoff time before trying to access the channel after a failure of transmission. It is calculated as given in Equation no. 7.

$$T_{backoff} = Uniform[0, CW_{min} 2^i - 1] \times T_{slot} \quad \textbf{(7)}$$

Where $CW_{min} \leq CW \leq CW_{max}$. $i$ shows the level of back-off. Its value is incremented up to $CW_{max}$. The attempt of re-transmitting the unsuccessful frame is keep on by the station or its maximum limit of retry count is reached. Also, $T_{slot}$ is the time slot. Equation 8 is giving the formula for its calculation.

$$T_{slot} = T_{CCA} + T_{air\_prop} \times SIFS \quad \textbf{(8)}$$

$T_{suc}$ is the success time and is a random variable representing the period for which a medium is sensed busy because of a success ongoing transmission process. Following Equation no. 9 gives formula for its calculation [22].

$$T_{suc} = T_{ack} + T_{wait} + T_{backoff} \quad \textbf{(9)}$$

While $T_{col}$ is collision time and is a random variable representing the period for which a medium is sensed busy by each station due to collision [22]. Equation no. 10 shows its calculation formula.

$$T_{col} = T_{ack} + T_{wait} + T_{backoff} \quad \textbf{(10)}$$

The values for both $T_{suc}$ and $T_{col}$ are dependent on transmission rate, the packet length and the overhead (bits). The specific transmission scheme (RTS/CTS, DATA/ACK) also effects on their values that is also reflected from the above given Equation no. 9 and Equation no. 10.

In Equation no. 6 and Equation no. 7, $SIFS$ is Short $Interframe\ Space$ that represents the length of time $(\mu s)$ and is required for some wireless interface in order to process a received frame and to respond with a response frame. In more simple words, this is the time difference when the first symbol of the response frame is in the air and the last symbol of the received frame is in the air. $SIFS$ is calculated as follows (Equation no. 11).

$$SIFS_{(\mu s)} = R_x RF_{delay} + R_x PLCP_{delay} + MAC_{pro\_delay} + R_x T_x T_{trunaround} \quad \textbf{(11)}$$

In Equation no. 6, $DIFS$ is Distributed Coordination Function's Interframe Space. $DCF$ is Distributed Coordination Function that is a basic MAC technique of $IEEE$ 801.11 based wireless LAN standard. It employs a CSMA/Ca with binary exponential backoff algorithm. If a station is interested to transmit, DCF requires from it to listen for the channel status for a DIFS interval $(DCF\ Interframe\ Space)$. If it is found that the channel is busy during the DIFS interval, the transmission by the interested station is deferred. Duration of DIFS can be calculated as follows.

$$DIFS = SIFS + (2 \times T_{slot}) \quad \textbf{(12)}$$

$T_{slot}$ has the value equal to the twice to that of time it takes for an electronic pulse to travel to the length of theoretical distance to its maximum between two communication nodes. For a link of 1 *Gbits*/*sce*, the time interval is 4.096 *µsec* and for 10 *Mits*/*sec* link, the time interval is 51.2 *µsec*.

The values of DIFS for different standards is given in Table 2.

**Table 2.** The Values of DCF Interframe Space for Different Standards

| Standard | $SIFS_{(\mu s)}$ | $Slot\ Time_{(\mu s)}$ | $DIFS_{(\mu s)}$ $[SIFS + (2 \times T_{slot})]$ |
|---|---|---|---|
| *IEEE* 802.11*b* | 10 | 20 | 50 |
| *IEEE* 802.11*a* | 16 | 9 | 34 |
| *IEEE* 802.11*g* | 10 | 9/20 | 28/50 |
| *IEEE* 802.11*ac* | 16 | 9 | 34 |

## 3.3 Forwarding Node Selection

Based on the discussion in above section and section 0, we come up with the final decision of optimal forwarding node selection that ultimately leads to load balancing in the network. Node $i$ collects the necessary information from its neighboring nodes $(N_i = |d(i-j)| \le r_i \forall_j$ where $r_i$ is communication range of node $i, j = 1,2,\ldots n$ and $i \ne j$ ) and calculates $LBIDA_j$ value.

In extended form, the calculation of $LBIDA_j$ for the optimal forwarding node for some neighbouring node, say $j$ is as follow:

$$LBIDA_j = \left(1 - \frac{B_c^j(t_1)}{\sum_{k=1}^{n} N_i[B_c^k(t_1)]}\right) + \left(\frac{s}{\left[1 - \left(\frac{T_{wait} + T_{col} + T_{backoff}}{T_{wait} + T_{col} + T_{backoff} + T_{suc}}\right)\right] \times Bandwidth}\right) \quad \textbf{(13)}$$

The node in the neighbor of $i$ having the highest value of $LBIDA_j$ is given the priority in selection. In addition, this model can be tailored to the required level of output with assigning the weighting factors $(\alpha, \beta)$ accordingly. The value of which varies [0, 1] with respect to giving preference to load balancing, or interference delay aware parameters. So, the Equation 13 is like

$$LBIDA_j = \left(1 - \frac{B_c^j(t_1)}{\sum_{k=1}^{n} N_i[B_c^k(t_1)]}\right)^a + \left(\frac{s}{\left[1 - \left(\frac{T_{wait} + T_{col} + T_{backoff}}{T_{wait} + T_{col} + T_{backoff} + T_{suc}}\right)\right] \times Bandwidth}\right)^\beta \quad \textbf{(14)}$$

Or in short form,

$$LBIDA_j = (IDAM_{ij})^\alpha + (LBM_j)^\beta \quad \textbf{(15)}$$

In our simulation, we consider Equation. 15 as final model of our proposed solution.

# 4 Performance Evaluation

The performance of the LBIDA routing metric is evaluated through extensive simulation using C++ programming language. We divide the performance evaluation into two parts. In the first part, we describe the simulation environment in detail using Figure 2. In the second part, we showed the performance of LBIDA routing metric against the WCETT metric by incorporating these metrics in AODV protocol.

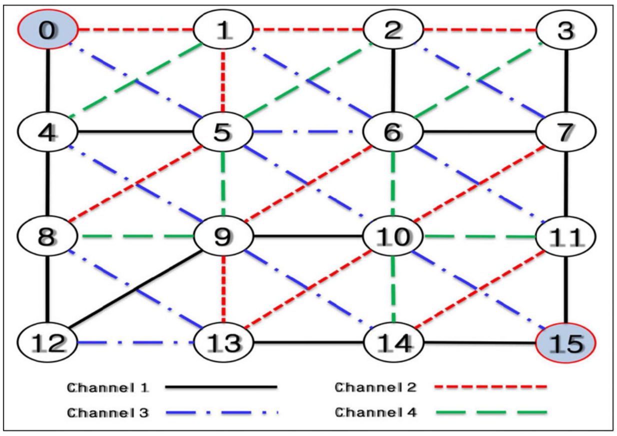


**Figure 2.** Simulation Scenario

The simulation environment for WMN is shown in Figure 2. The scenario consists of 16 static MSTA which are randomly deployed in a 4x4 grid in a 400m x 400m square region. It is assumed that each MSTA in the network has 100m transmission range. The interference range is set to approximately equal because all mesh routers have similar transmission powers. The source nodes send Constant Bit Rate (CBR) traffic using User Datagram Protocol (UDP). The packet size is 1024 bytes with a sending rate of 100 packets/second. The value of $\beta$ was taken as 0.3 for calculation of WCETT and LBIDA. The value $\beta$ is taken as an optimum value because of its previous usage in WCETT algorithm. The default simulation parameters are shown in Table 3.

**Table 3.** Simulation Parameters

| Parameters | Default values |
|---|---|
| Network topology | 400x400m |
| Number of mesh stations | 16 |
| Number of radios | 2 |
| Number of channels | 4 |
| Packet size | 1024 bytes |
| Interference range | 100m |
| Traffic model | Constant Bit Rate (CBR) |
| Queue size at mesh stations | 50Kbytes |
| MAC protocol | IEEE 802.11 |
| CBR sender's rate | 100 packets/sec |
| Bandwidth | 11Mbits/sec |

As shown in Figure 3, different tests were performed for packet loss ratio among LBIDA and WCETT routing metrics. The results reveal that as the number of traffic flow increases, the packets drop rate also increases. However, LBIDA routing metric takes account of the channel interference and load balancing. Therefore, the number of drop packets in the case of LBIDA is lower than that of WCETT routing metric. On the hand, WCETT is suffered from high packet loss because of it does not consider the load balancing on a link in WMN.

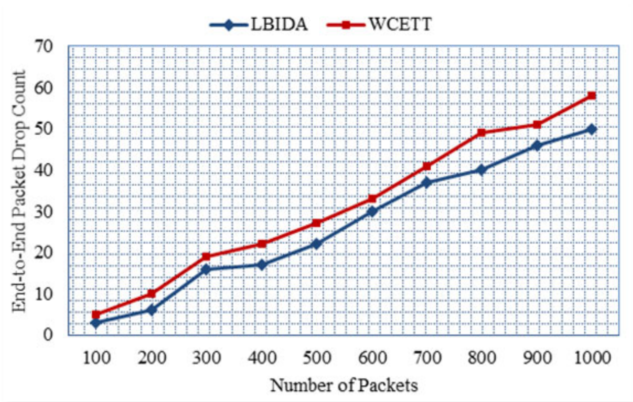


**Figure 3.** Count of Dropped E2E Packets

The LBIDA routing metric is compared with the WCETT in the context of average E2E delay as shown in Figure 4. Various traffic loads are injected into the network, and we found that the LBIDA routing metric selects route with less interference as compared to WCETT routing metric. As the flow of data increases into the network, the E2E delay also increases because the E2E delay directly depends on the interference level on a link. LBIDA shows less E2E as compared to WCETT because the WCETT always calculate ETT on each link. Therefore, the WCETT shows greater delay. However, the LBIDA always considered load on a link and therefore avoiding congestion in the network. Thus, significantly reduces the E2E delay on a link.

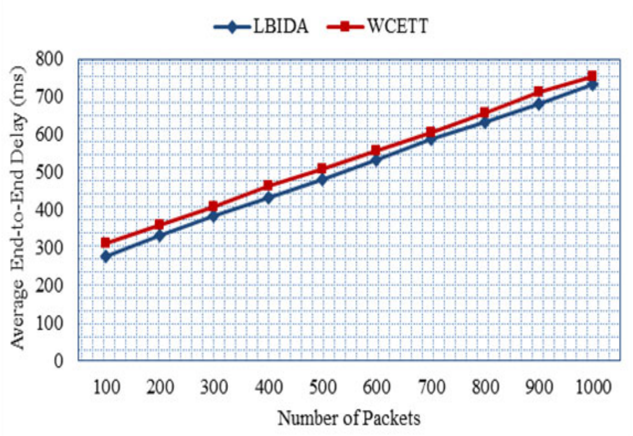


**Figure 4.** Average End-to-End delay

The LBIDA and WCETT are compared in the context of load balancing, which is measured by a normalized variation coefficient of carried load at each mesh node as shown in Figure 5. The LBIDA shows improvement in load balancing compared with the WCETT. It is due to minimizing the effect of interference and selection of an optimum route in the proposed WMN scenario. The simulation results show that the proposed routing metric outperform to the metrics present in the current literature. Thus, the proposed metric can deliver efficient results by using it in the real time scenario of WMN in different fields such as IoT, Cyber Physical System, Machine to Machine, etc.

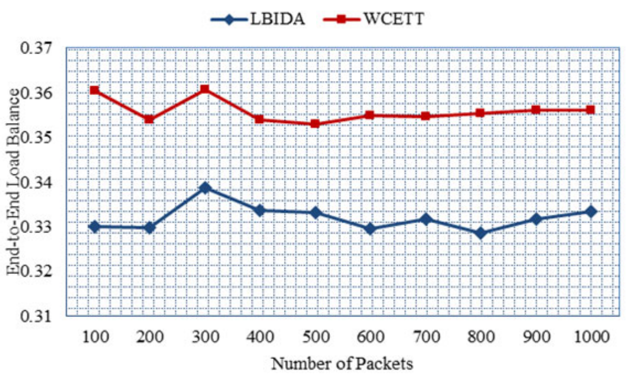


**Figure 5.** Load Balancing Effect

Figure **6** shows the performance efficiency $[\xi = \left(1 - \frac{Result\ of\ 1st\ Algo}{Result\ of\ 2nd\ Algo}\right) \times 100]$ of proposed scheme over WCETT with respect to Load Balancing effect, End-to-End delay and Number of Packets dropped against varied number of packets i.e. 100, 200, …, 1000. E.g. In a network flow of 100 packets, performance efficiency of LBIDA, the proposed scheme with respect to load balancing effect is about 17% higher compared to WCETT, with respect to End-to-End delay is about 10% better and with respect to no. of packets dropped is about 40%. Similarly, in a network flow of 800 packets, the performance efficiency of LBIDA is 13%, 3% and 18% is higher than to that of WCETT with respect to load balancing effect, end-to-end delay, and no. of packets dropped respectively.

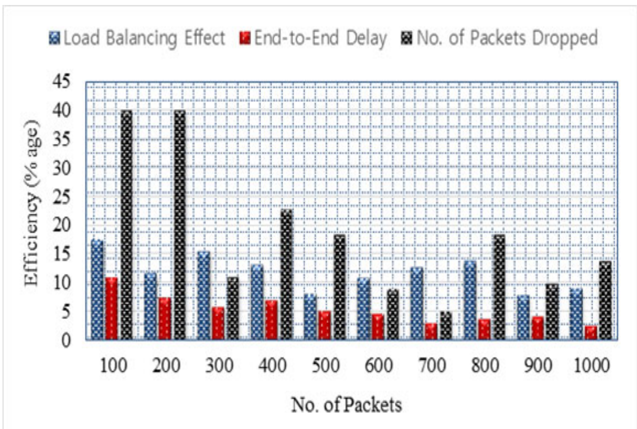


**Figure 6.** Performance Efficiency of Proposed Scheme over WCETT in Various Parameters

## 5 Conclusion

In this paper, we proposed a new routing metric i.e. LBIDA for multi-channel, multi-hop IoT aware WMNs. This metric obtains the information of intra and inter-flow interference and traffic load to efficiently utilize it for the better performance in IoT scenarios. The proposed scheme efficiently reduces the interference delay and balances the load among different links in WMNs. The simulation results showed that the proposed scheme can be incorporated into a load balancing path discovery algorithm. This algorithm is further used to design a load balancing protocol which chooses a path that delivered a high throughput, reduce the average end to end delay with minimized interference, and can help in increasing the network capacity effectively. Finally, the proposed scheme is compared with the existing routing metric and it shows superior performance over similar schemes. Merging of artificial intelligence scheme especially from Ant colony optimization [23] with the proposed scheme can optimistically improve the system performance in load balancing aspects.

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