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A Modified Bandwidth Prediction Algorithm for Wireless Sensor Networks

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In wireless sensor networks, the available bandwidth is considered one of the most important technique to select the best route and send data safely. The current paper suggest an algorithm which is used to send data over WSN by suggesting an algorithm namely, Enhanced Bandwidth Prediction (EBP) algorithm, which is employed to choose the route with less overhead which aid in reducing the congestion of the network and send the data through it. EBP algorithm has been utilized to choose the route depending on its current bandwidth and the percentage of consumed bandwidth and to compute the transmission rate value. Moreover, this algorithm aids in asking the sender to adapt this value in line with this rate helping to reduce the congestion problem in a specific channel which is reflected in quality of the whole network. The results show that this algorithm has a good improvement over other algorithms by in terms of delay and packet delivery ratio.

Keywords: WSN, bandwidth, bandwidth estimation, congestion, wireless channel

1. INTRODUCTION

In recent times, the use and importance of wireless sensor networks have increased significantly. The term “wireless sensor network” (WSN) refers to a common form of lossy, low-power network. However, various WSN applications call for long-term and dependable services, such as in the case of disaster management and healthcare. As a result, various energy-efficient plans are needed to deliver dependability [1].

In recent years, Wireless Sensor Networks (WSN) have grown significantly. Their intrinsic limitations (battery, computing power, *etc.*) and unique traits (such as enormous network size) present significant research challenges [2, 3]. In order to boost the overall performance of the network and render more diverse communication capabilities in combination with greater data rates, innovative approaches including network coding and node cooperation have been developed [4-6] These advancements assert the need for new protocols.

There are many elements to consider when optimizing any algorithm for sensors usage, including: network connection, Sensors network distance, and mobility consuming [7-9]. Optimization of sensor deployment has been used to be a neighbor nodes-hard problem

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[10-12]. Many scientists are interested in find a solution for bandwidth consumption problems by using many methods like adaptation intelligence optimization algorithms. A lot of techniques have been proposed to optimize the network [13]. Fig. 1 represents the wireless network with nodes deployment [14, 15].

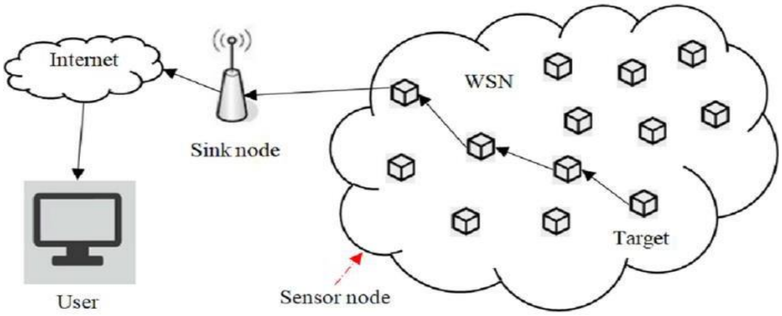


Fig. 1. Wireless network with nodes deployment.

2. RESEARCH AIM AND OBJECTIVES

This research aims to develop an algorithm which satisfies the following objectives,

- To develop an enhanced bandwidth algorithm for WNSs
- To develop an algorithm with high energy efficiency and sufficient packet delay
- To provide the WSN protocol which has the ability to operate separately as well as in combination with other bandwidth schemes.

3. LITERATURE SURVEY

In the existing literature, numerous more enhanced Bandwidth algorithms are suggested for WSNs, including real time system, adaptive Bandwidth, and, hybrid systems [16]. In essence, several bandwidth schemes have relationships with one another. For instance, "flower pollination algorithm" which considered the most important method that has been used to solve the optimization problem [17]. Various studies examine the effectiveness or improvement of bandwidth in WSNs, which is motivated by the impact of distance and the locations of the sensors [18]. Due to the inclusion of network coverage, these schemes inherit many drawbacks, making them more appropriate for moderately steady wireless situations.

The author in [19] reported that through cooperative relaying, usually over a wireless network, cooperative bandwidth increases transmission efficiency but it has also many problems in network coverage. The author in [20] re-examined the advantages of cooperative Dong and others algorithm in light of the fact that building energy- efficient protocols were not the main consideration when cooperative Dongs algorithms were initially presented. As it happens, energy efficiency has increased. However, in multi-hop wireless networks, the collaboration between the source, sink, and intermediate nodes would be particularly challenging [21].

A channel-aware Bandwidth algorithm carefully chooses the frame transmission/retransmission timing moment by incorporating the channel status estimation into the feedback mechanism. Such a plan takes into accounts choosing the best channel time for transmission. However, because the optimization is just local, the optimality of the global effect cannot be guaranteed. According to several researchers, the MAC should switch from the current MAC protocols to the BW scheme with fuzzy logic control to decrease channel collisions and boost delivery rates. However, the scheme's primary goal mentioned in these studies is not to save energy.

For wireless sensor networks, studies suggest a high energy-efficient link layer adaptive error correction technique [22]. The mechanism, which takes its name from the weighted fusion algorithm, combines the traditional BW and modified hybrid BW and is built to accommodate various link layer frame lengths and communication distances [23].

Based on this literature survey, it can be seen that current energy-efficient BW systems are not given enough thought to and addressed the issue of shortening the path of transmission for BW packets and reducing the number of BW-related packets. Therefore, it implies that it is urgently required to build a new ARQ system having improved energy efficiency.

4. PROPOSED ENHANCED BANDWIDTH PREDICTION (EBP) ALGORITHM

In wired network, the available bandwidth can be calculated by finding the minimum available bandwidth of the links along the available path [24] But in wireless, the bandwidth expending is a great problem on account of wireless topology [25, 26]. In the current paper EBP is used to find the best route for the enhanced layer frames only, and the Base Layer frames is selected its route according to the mobility, distance and available power of the nodes, in order to reduce the calculation overhead which is lead to high end to end value and network overload the proposed EBP has used to predict the available bandwidth which consists of two stages:

First Stage: internal estimation is used to estimate the available bandwidth of each node in the network, then this value will be used to calculate the available bandwidth in the whole routes.
Second Stage: is utilized in order to predict the bandwidth which will be used by the transferring of the data. When it passed by the using specific route with the (N) hops

This process contains two main stages, first one, each hop predicts its current bandwidth. second one, hops in the route will calculate the newest values of estimation, in order to get the accurate results for prediction as follows,

(A) First Stage: Internal Prediction

In this paper, the available bandwidth is calculated depends on the maximum throughput value which can be transferred between the two neighbored nodes [5, 6], not as the traditional way which is calculated the available bandwidth depends on the unused bandwidth in the link [15, 16].

In EBP, each node will be predicted its throughput value with all other neighbored nodes by using Eq. (1)

$$\text{Throughput} = \text{Size of Sent packets (bit)} / (\text{Received time} - \text{Send time(sec)}). \tag{1}$$

This value was obtained by sending extra packets in order to find the throughput, which in turn excess the network load. Other studies make a modification to the MAC layer which needs to consume more resources in transmission, so providing an enhanced method with less overhead and minimum resource consuming is a necessary task.

In this paper, the throughput has estimated in accurate way based on the Hello message packets, which is used to build the neighborhood table in routing [7-9]. EBP has two main features, the first feature is the implementation of it in a network layer, and the second feature is that the network overload will be reduced because it depends on Hello message which is used in the network communication system.

Let us considered that node1 is neighbor of node2, to predict the throughput between these two nodes, node1 will send Hello packet to nodes2, and sending time is recorder at node1, when node2 receives Hello packet, it will reply to node1 by ACK which contains the receiving time of the packet, so node1 will calculate the throughput depends on the sending and receiving times of the packet. So that the predicted available bandwidth will be calculated depending on channel busy status, differences time, transmission data times and the overhead in MAC layer. The summery of the EBP local prediction algorithm, when there are two nodes need to predict the available bandwidth between them, the sender node will calculate the throughput value by using Hello packets information. In order to get more accurate result, each node will calculate the newest ABW depends on the ABW in two different periods of time. And the final equation for ABW (Available bandwidth) will be calculated by using Eq. (2) [4] as follows,

$$\begin{aligned} ABW &= \frac{RTS+CTS+Hello+ACK+RTS+CTS+HelloACK}{Transmission\ time - sending\ time} \\ &= \frac{RTS+CTS+Hello+ACK+RTS+CTS+HelloACK}{TQ+(TH+THA+CAT+TCO+COT)\,XRT+\sum BOT} \end{aligned} \tag{2}$$

where

RTS is request to send
CTS is clear to send
TQ is the queuing time
TH is the hello packet time
THA is hello acknowledge time
CAT is collision avoidance time
COT is the control overhead time
BOT is the back – off time for retransmission

The calculations parameters concern the effect of the channel interfering and fading errors, which means that if the channel contention is high, then the variation between transferring and arrivals times is also high, so the ABW will be low according to the Eq. (2).

In the second step, the nodes in the route will calculate the newest values of available bandwidth estimation value, in order to get the more accurate and stable system responsiveness by using Eq. (3),

$$ABW(T_I) = \begin{cases} ABW(T_{I-1}) + (1-\alpha) * ABW(T_{I-1}) & t > 0 \\ ABW(T_0) & t = 0 \end{cases} \quad (3)$$

where

- $ABW(T_I)$ is the newest and actual available *BW*.
- $ABW(T_{i-1})$ is the available *BW* at the previous period of time which equals to T_{i-1}.
- $ABW(T_0)$ is the initial value of the available *BW*.

(B) Second Stage: External Prediction

The second stage of the bandwidth prediction is the prediction the expended bandwidth in each route, to verify if the nodes in the specific route have the ability to support the requested bandwidth or not. In this paper, the proposed algorithm which is used to calculate the consumed bandwidth depends on the contention content value (CCV) which is used to predict the consumed bandwidth during a data transmission. CCV represents the ratio between maximum bandwidth demand and actual bandwidth available. An increase in contention ratio results in an increasing number of users attempting to use the actual bandwidth at a given period of time. It is calculated by using Eq. (4) as follows,

$$CCV = N_{req} + N_{rep} \quad (4)$$

Given that

- N_{req} and N_{rep} are the number of nodes from the sender to receiver node. (These two numbers can directly get from the RREQ and RREP in IVRP.)

The expended bandwidth could be obtained in the receiver node by multiply the CCV in the route with the requested bandwidth which is sent by the sender to estimate the consumed BW by using Eq. (5) as follows,

$$CBW = CCV * RBW. \quad (5)$$

Given that

- CBW is the consumed bandwidth,
- RBW is the requested bandwidth.

As shown in Flowchart (1), the summery of the estimation algorithm, when the sink receive data request, it calculates the CBW by using Eq. (5) and its ABW by using Eq. (3), then compares these two values. If the CBW is less than its ABW, it asked the sender to increase the transmission rate value according to the ABW. And send ACK to the sender that has the ABW of the receiver. Otherwise, if the CBW is greater than the ABW then the sender should reduce the data transmission according to the ABW.

5. RESULTS, ANALYSIS AND DISCUSSIONS

The proposed EBP algorithm has checked with other two algorithms including ETR-

FC and AProbing which proposed by [15, 16], respectively. In this process, NS2 simulation has been employed to enable the validation of the EBP algorithm. The findings of the simulation are described as follows.

The three bandwidths estimate algorithms’ throughputs depicted a decrease as the number of nodes rises and vice versa. The usage of EBP, followed by ETFRC and AProbing resulted in the maximization of throughput value. The three algorithms' greatest throughputs can be examined at the initial stage of the simulation. The increase in throughput was achieved with EBP between (30 to160 Kbps). The key factor causing EBP's high throughput value is that it may transfer data packets according to the bandwidth that is available, lowering the likelihood of an error during a time slot and eventually resulting in excellent performance. Additionally, it takes into accounts the fact that the value of interference range is twice in comparison to the transmission range. This reduces the likelihood of congestion without influencing the other nodes in the network topology by clearly implying that hops more than three nodes away from the sender have insufficient accessibility to the wireless channel.

(A) Packet Delivery Ratio (PDR)

The three algorithms exhibit the largest PDR value at the start of the simulation when the network is tiny in Table 1. With the increase in number of nodes, the likelihood of congestion rises as well, which lowers the proportion of delivered packets to send packets. As a result, this value falls as the number of nodes rises. The three methods’ differences are in the range of 1 to 2 percent, and they all result in PDR values above 95 percent. Thus, the suggested method can increase the accuracy of bandwidth estimation and decrease congestion, which lowers the amount of network packets that are not delivered. This is signified by the highest PDR value by EBP followed by ETFRC and AProbing algorithms, respectively. The ratio of packets received rises as a result of this phenomenon. These outcomes demonstrate the applicability of these methods in a broad network.

Table 1. Packet delivery ratio results.

No. of sensors	ETFRC	Probing	EBP
15	85.11	81.13	78.24
30	86.47	78.22	77.56
50	85.55	77.13	76.98
80	84.84	76.50	72.61
110	85.65	72.01	68.95

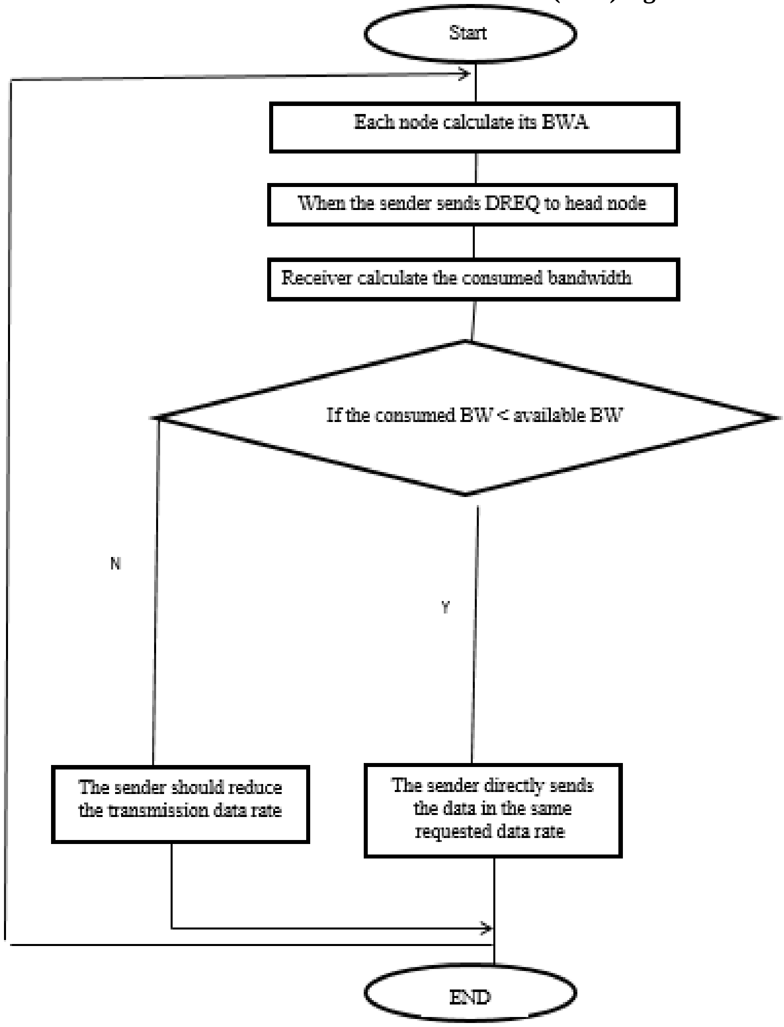
(B) End-to-end delay

This value in whole scenarios grows with the number of nodes. Whole algorithms display a short delay at the inception of simulation, yet there is a significant variance between these algorithms (approximately 0.080 sec). The difference between them is obvious when the network is small. However, in case the network grows, the difference between ETFRC and AProbing becomes less noticeable. Additionally, the difference between the EBP is slightly altered, and the proposed EBP illustrates smaller delays as compared to AProbing and ETFRC. The EBP’s end-to-end delay calculation approach, which solely relies on the swapping of the nodes with the maximum bandwidth during the transmission period, is the primary cause of the minimal end-to-end value in this algorithm. The intermediate node will quickly and efficiently replace the current value with the highest one by comparing its value to the available bandwidth value. The proposed EBP results in improvements between (0.080 and 0.12); however, because there are more than 100 nodes, this improvement is reduced to (60 to 70) as shown in Table 2.

Table 2. Delay value results.

No. of sensors	ETFRC	Probing	EBP
15	241.21	220.31	124.19
30	243.25	241.30	129.22
50	245.33	233.23	157.28
80	246.32	243.33	179.25
110	249.77	248.23	184.25

Flowchart 1: Enhance Bandwidth Prediction (EBP) algorithm



(C) Throughput

In all prediction methods, as the number of sensors grows the values of throughputs also decreased. All of the prediction algorithms display a small throughput values at the inception of simulation, yet there is a significant variance between these algorithms (approximately 50Kbps). The difference between them is obvious when the network is small. However, as the network becomes big, the difference between AProbing and ETFRC becomes small. Additionally, the difference between them and the EBP is greatly altered, and the proposed EBP illustrates great throughputs as compared to AProbing and ETFRC. The EBP's throughput calculation approach is the primary cause of the greater throughput value in this algorithm. The proposed EBP results in throughput improvements between (20 and 80 Kbps); however, because there are more than 100 nodes, this improvement is increased to (70 to 90) as shown in Table 3.

Table 3. Throughputs results.

No. of sensors	ETFRC	Probing	EBP
15	275.24	270.32	287.32
30	210.25	205.30	270.33
50	205.20	201.32	252.32
80	136.21	121.32	244.23
110	110.32	105.30	221.21

(D) Number of Dropped Packets.

The all algorithms show the smallest value when measure this parameter, at the start of the simulation when the specific area is small. As the increase of network number of sensors, the likelihood of congestion increases as well, which reduces the value of delivered packets to send packets. As a result, this value falls as the number of sensors rises. However, the suggested method can increase the accuracy of bandwidth estimation and decrease congestion, which reduces the amount of network packets that are not delivered. This is signified by the smallest dropped packets value by EBP followed by AProbing and ETFRC algorithms, respectively. The ratio of packets received rises as a result of this phenomenon. These outcomes demonstrate the applicability of these methods in a broad network.

Table 4. Dropped packets results.

No. of sensors	ETFRC	Probing	EBP
15	11	14	9
30	14	17	11
50	16	19	12
80	17	22	13
110	23	25	15

6. CONCLUSIONS

In the current paper an enhanced algorithm for improving the performance of wireless sensor networks at a whole by proposed an algorithm which estimates the bandwidth called Enhanced Bandwidth Prediction (EBP) algorithm, which is choose the route with less overhead which aid in reducing the congestion of the network and send the data through it. NS2 simulation has used to verify the results and the results of this algorithm show that this algorithm has a good improvement over other algorithms by in terms of delay and packet delivery ratio with a 30% percentage than the other previous algorithms. This work also deals with optimization of WSNs coverage by random expansion realized by change the location of some sensor nodes. Hence the sensor nodes selection and locations are the heart of the matter. By Assuming that all hops should be change their location. but some Sensor hops are stable in real simulation. Therefore, gathering movement and stable hops to enhanced WSN coverage is a most important factor. Aside from that, In the future Internet of Things (IoT), not only sensor nodes but also sinks can be change their location. Optimizing WSN coverage make the study becomes more complex.

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