Traffic Management in Wireless Sensor Network Based on Modified Neural Networks

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Abstract: *Wireless Sensor Networks (WSNs) are event-driven network systems consist of many sensors node which are densely deployed and wirelessly interconnected that allow retrieving of monitoring data. In Wireless sensor network, whenever an event is detected, the data related to the event need to be sent to the sink node (data collection node). Sink node is the bottleneck of network there may be chance for congestion due to heavy data traffic. Due to congestion, it leads to data loss; it may be important data also. To achieve this objective, soft computing based on Neural Networks (NNs) Congestion Controller approach is proposed. The NN is activated using wavelet activation function that is used to control the traffic of the WSN. The proposed approach which is called as Modified Neural Network Wavelet Congestion Control (MNNWCC), has three main activities: the first one is detecting the congestion as congestion level indications; the second one is estimated the traffic rate that the upstream traffic rate is adjusted to avoid congestion in next time, the last activates of the proposed approach is improved the Quality of Services (QoS), by enhancement the Packet Loss Ratio (PLR), Throughput (TP), Buffer Utilization (BU) and Network Energy (NE) . The simulation results show that the proposed approach can avoid the network congestion and improve the QoS of network.*

Keywords: Wireless Sensor Network; congestion control; QoS; Neural Network; wavenet **.**

الخلاصة: شبكات الاستشعار اللاسلكية (WSNs) هي أنظمة شبكة يحركها حدث تتكون من أجهزة الاستشعار, العقدة الكثيرة التي تنتشر بكثافة ومترابطة لاسلكيا التي تسمح استرجاع بيانات الرصد .في شبكة الاستشعار اللاسلكية ,كلما تم الكشف عن حدث ,فان البيانات المتعلقة بالحدث بحاجة إلى أن ترسل إلى عقدة رئيسة (عقدة جمع البيانات .)العقدة الرئيسة هو عنق الزجاجة للشبكة قد تكون هناك فرصة للاحتقان بسبب حركة البيانات الثقيلة .بسبب الازدحام ,فإنه يؤدي إلى فقدان البيانات ,بل قد تكون البيانات الهامة أيضا .لتحقيق هذا الهدف,تم اقتراح الحوسبة المرنة على أساس الشبكات العصبية (NN) و نهج وحدة تحكم الازدحام .يتم تنشيط NNباستخدام وظيفة التنشيط المويجات التي يتم استخدامها للسيطرة على حركة المرور من . WSN النهج المقترح وهو ما يسمى شبكة مراقبة الازدحام ذات الشبكه العصبية بالمويجات المعدلة , (MNNWCC) لديها ثلاثة أنشطة رئيسية :الأول هو الكشف عن الازدحام ومؤشرات مستوى الازدحام؛ يقدر ثانية واحدة معدل حركة المرور أن معدل حركة المرور المنبع يتم تعديله لتجنب الازدحام في المرة القادمة ,والنشاط الأخيرة من النهج المقترح هو تحسين نوعية الخدمات(جودة الخدمة ,)من خلال تحسين نسبة فقدان الحزمه ،(PLR) والإنتاجية , (TP) استخدام الاحتياطي (BU) و شبكة الطاقة . (NE) وتبين نتائج المحاكاة أن النهج المقترح يمكنه تجنب ازدحام الشبكة وتحسين جودة الخدمة للشبكة.

1. Introduction

Wireless Sensor Networks is a network of large number of sensor nodes deployed either randomly or deterministically over a large geographical area. It has a capability of sensing, processing, and communication over a wireless channel and to withstand in harsh environment [1,2].wherever sensor nodes sense physical phenomenon begin report the event through wireless links to sink (base station). The sink node is most powerful which is used as gateway to the wired or other wireless network and it is doing data collecting and processing [3,4]. Once a target event occurs, a sudden surge of data traffic will be triggered by all sensor nodes in the event area, which may easily lead to network congestion when offered traffic load exceeds practical network capacity.

The very important issue in the WSNs is congestion. There are various reasons for congestion. They are node level congestion and link level congestion [5, 6 and 7]. Node level congestion occurs when the number of incoming packets is greater than the available buffer space. Link level congestion occurs when multiple active sensor nodes within range of one another attempt to access transmission medium simultaneously, packets that leave the buffer may fail to reach next hop as a result of collision among sensor nodes, as shown in Figure(1).

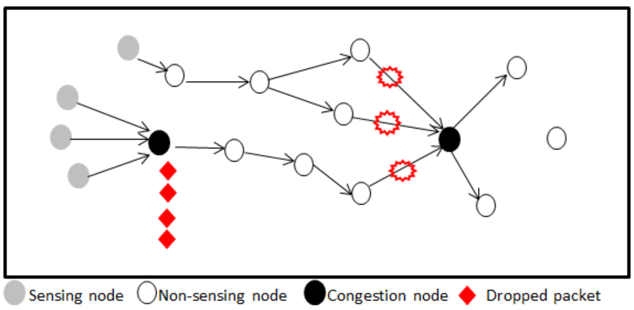


Figure 1: Congestion in a wireless sensor network [3]

Based on these considerations, this paper aims to address these problems by providing a congestion control scheme based on Modified Neural Network with wavelet activation function. This scheme considers the current buffer occupancy status as input to neural and the estimated traffic in next time as output. Finally, rate adjustment can be made according to those decision values.

The rest of the paper is organized as follows: Section II Related work .Section III discusses the network model. Section IV introduces the proposed congestion control approach. The performance evaluation of proposed congestion control is carried out in Section V. Section VI is Conclusion.

2. Related work

Researchers have a lot of in-depth study of congestion control for wireless sensor networks. In 2005 [8], a predictive congestion control scheme for wireless sensor network in concert with Distributed Power Control (DPC) is proposed. By using the channel quality and node queue utilizations, the onset of network congestion is predicted and congestion control is initiated. In 2010 [9], a new approach for confronting congestion while achieving fairness by using a suitable algorithm for WSNs is described. In 2011[5], an algorithm is proposed for Wireless Multimedia Sensor Network (WMSN) ,where a Fuzzy Logical Controller (FLC) is used to estimate the output transmission rate of the sink node. In 2012[7] efficient fuzzy based congestion control algorithm is proposed which takes into consideration the node degree, queue length and the data arrival rate as input parameters for congestion detection and the output is given in the form of fuzzy variables which indicates the level of congestion.

3. The network model

The network model consists of a set of N sensor nodes, distributed randomly over coverage area and one sink node in center of the area. Sensor network node has two activity, a nodes can generate data traffic, as well as route traffic originated by other nodes. Based on event-driven sensor networks in general is acceptable load condition, if the sense's node has been detected events will suddenly become active; encode the information into packets, these packets will then be forwarded, possibly via multiple hops, to a sink node using shortest path routing. The model of the network is shown in Figure(2).

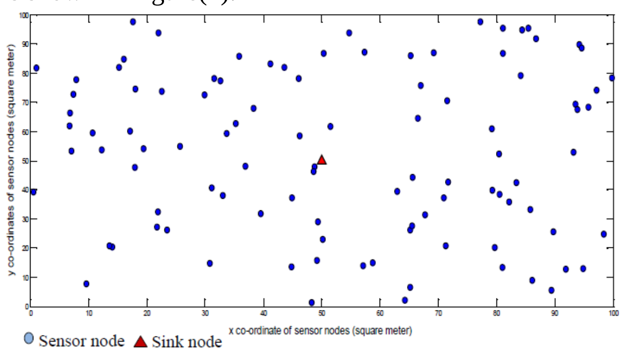


Figure 2: Network model for simulation

Each sensor Si will transmit data toward sink with Bit Rate BR(Si). All the sensor nodes must be sending within the available capacity of the network channel. This explained as shown in eq.(1).

$$\sum_{i=1}^{N} BR(S_i) \leq \text{Channel capacity} \quad \dots (1)$$

4. Congestion Control Approach

Congestion Control Components are three units. Congestion Detection unit (CDU) which is used to safely detect if the problem has occurred or is going to happen, Rare Adjustment Unit (RAU) calculates the new rate for all nodes and the new rate is sent to the Congestion Notification Unit (CNU) which is responsible for notifying all the nodes of the new rate [5]. These components are explained in the following sections

A. Congestion Detection unit

Accurate and efficient congestion detection plays an important role in congestion control of sensor networks. To detect congestion, the level of congestion should be quantified to provide a fine-grained congestion control [10]. Congestion detection refers to identification of possible events, which may build-up congestion in the network. In order to precisely measure local congestion level at sink node (bottleneck node), the proposed approach calculates the sum of reached traffic *(RT*) in the current period (*t)* to buffer's sink and PLR. Different *RT* states reflect different network loading. Corresponding approach is adopted to increase or decrease packets rate of active sensor nodes.

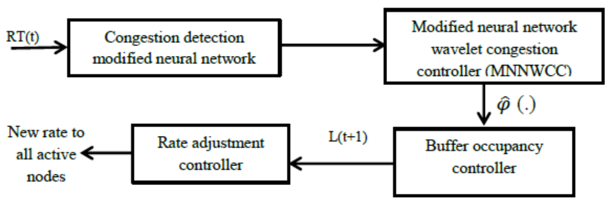
In other words,

If (PLR > 0) and (RT(t) > 90% of SBS)
CIF= true
Then Decrease sending rare of active sensor node based on Controller
Else CIF=false

Where SBS is size of buffer in sink and CIF is congestion indication flag.

B. Modified Neural Network Wavelet Congestion Control (MNNWC)

Figure(3) explains the congestion control model that is proposed in this paper. The model consists of Congestion detection modified neural network as explained in section A**,** Modified Neural Network Wavelet Congestion Controller (MNNCC),which is used to control the unknown traffic of the sources sensor with different rate. A three layered Feed-Forward Neural Network (FFNN) is adopted to accomplish traffic signal controller. The weights of the layers in NN are updated using Back Propagation (Bp) Training algorithm.



The online training is used to control the traffic.

Figure 3:Congestion Control Model

The input to the FFNN is the total traffic that reached to sink buffer at the current time. Output of the FFNN is ˆ(RT(t)) which represents the buffer occupancy in next time.

The transfer function of hidden is the modified of the wavelet function which is known as Superposed Logistic Function (SLOG) [11] and is described as:-

$$f(net)=\left[\frac{i}{(1+e^{(-net+1)})}-\frac{1}{(1+e^{(-net+3)})}-\frac{1}{(1+e^{(-net-3)})}+\frac{1}{(1+e^{(-net-1)})}\right] \quad ...(2)$$

While a modified SLOG function (MSLOG) is described as:-

$$f(net)=k*\left[\frac{1}{(1+e^{(-net+1)})}-\frac{1}{(1+e^{(-net+3)})}-\frac{1}{(1+e^{(-net-3)})}+\frac{1}{(1+e^{(-net-1)})}\right] \quad ...(3)$$

Where $net=\frac{(RT*W)-X}{Z}$, RT= input vector and W =weight of hidden layer. The parameters k,X,Z

are selected by trial and error. The derivative of eq. (3) is described as:-

$$\acute{f}(net)=k*\left[\frac{e^{(-net+1)}}{(1+e^{(-net+1)})^2}-\frac{e^{(-net+3)}}{(1+e^{(-net+3)})^2}-\frac{e^{(-net-3)}}{(1+e^{(-net-3)})^2}+\frac{e^{(-net-1)}}{(1+e^{(-net-1)})^2}\right] \quad ...(4)$$

In Figure (3), the Buffer occupancy controller is the desired buffer occupancy at sink node which is equal to SBS to achieve QoS. This can be described in eq.(5) [8] and the buffer occupancy error is described as:

$L(t+1) = (SBS-\varphi\hat{}(net)) + g\,.e(t)$ **...(5)**

$e(t) = RT(t)\ SBS$ **...(6)**

Where g is the gain parameter ($0 < g < 1$), L(t+1) is the estimated traffic load of network in next time and e(t) is buffer occupancy error .The estimated traffic that calculated from above controller is then divided among the upstream active node proportionally to rate of node in previous time to achieve fairness among node, this is the function of the rate adjustment controller. This can be explained as:

$$BR(S_i(t+1)) = L(t+1).\frac{BR(S_i(t))}{\sum_{i=1}^{m} BR_i} \quad ...(7)$$

Where m is sum of number of active node, the new rate BR(Si (t+1)) is communicated to upstream node Si to avoid congestion in next time. So the Si increase or decrease its rate according to the value of BR(Si (t+1)) that reached, nevertheless it should be noted that the rate must not be greater than its maximum rate else it set the rate to its maximum rate also the rate must not be less than its minimum rate else it set the rate to its minimum rate. Figure (4) Shows the flow chart of the proposed approach.

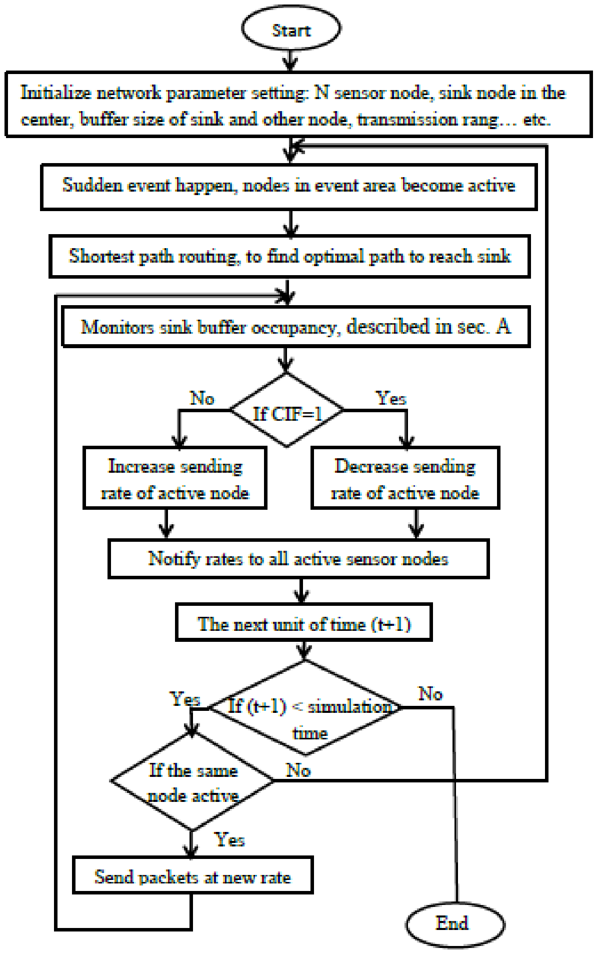


Figure 4: The flow chart of the proposed approach

The QoS that can be achieved is represented by PLR, BU,TP and NE. the PLR is:

PLR= PL/RT

Where PL=packet loss. The buffer utilization is:

BU= RT/SBS … (9)

The Throughput is given as:

TP= number of packet received by the sink buffer/RT … (10)

The Network Energy is given as:

NE=PL/ total number of packet received by the sink … (11)

5. SIMULATION RESULTS

This section presents simulation performance evaluation of the proposed Congestion Control approach. The simulations have been conducted in MATLAB (R2012a). The proposed network model comprises of 100 stationary sensor nodes randomly deployed over (100 ×100 m2) area with more than one source targeting to a single sink, sink node in the center of coverage area. The largest communication distance is 25 m between nodes. The buffer in sink node can hold 250 packets and buffer length of each node is 50 packets. The data packet are generated from sources are transmitted toward the sink node through multi-hop shortest path algorithm. Performance of the network is evaluated by calculating the QoS parameters: Buffer Utilization, Network Energy, Packet Loss Ratio and Throughput. Fig.(5) shows the number of active sensor node relative to time, it's clear from the figure that the number of sensor nodes that can be activated is between 10 nodes to 37 nodes. This is necessary to examine the performance of the proposed algorithm with different situation. Fig. (6) shows the number of packets arrives to the sink node, it is clear from figure that the MNNWCC has performance better than NNCC and from the network without controller. In Fig. (6) the MNNWCC minimizes the number of packets arrives to the sink node when the congestion occurs in the network better than NNCC, while the network without controller many packets arrive to the sink node and this will effects on the QoS of the network. Fig. (7) shows the PLR, it's clear from that figure the MNNWCC is performance better than NNCC and absolutely better than the network without controller. This is because the MNNWCC has intelligent methodologies that help the network to improve its QoS. The proposed approach which is based on MNNWCC has the ability to manage the traffic that comes to the sink node better than NNCC. Fig. (8) shows the BU, it's clear from that figure the MNNWCC is performance better than NNCC and absolutely better than the network without controller. Fig.(9) Shows the TP, it's clear from that figure the MNNWCC is performing better than NNCC and absolutely better than the network without controller. Fig. (10) Shows the NE, it's clear from that figure the MNNWCC is performance better than NNCC and absolutely better than the network without controller. From the results obtained, one can notice that when the number of sensor nodes increased the opportunity of congestion increased too; this is appeared clearly in Fig. (6) when the number of packets arrives to the sink node increased the network without controller has congestion because there are many packets arrive to the sink buffer and that is effects on the QoS in Figures (7, 8 and 9). In contrast, when MNNWCC is used as controller the packers arrive to the sink node is reduced in order to avoid congestion in sink buffer and to improve the QoS in the whole network. The performance of MNNWCC as a controller is more efficient than the performance of NNCC; this is obviously appeared from the given results. To illustrate more, consider Fig. (7) during time interval 28 unit of time, the PLR is 0.2604 so the proposed approaches tried to adjust the rate of the active node to avoid buffer overflow. This is evident in time interval 29, NNCC and MNNWCC reduced PLR to 0.06716 and zero respectively.

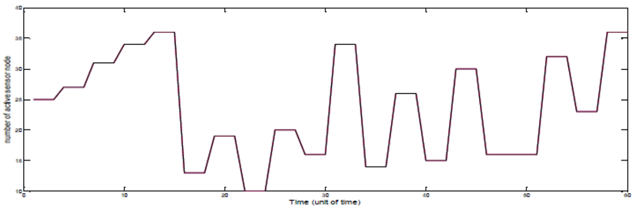


Figure 5: The number of active sources

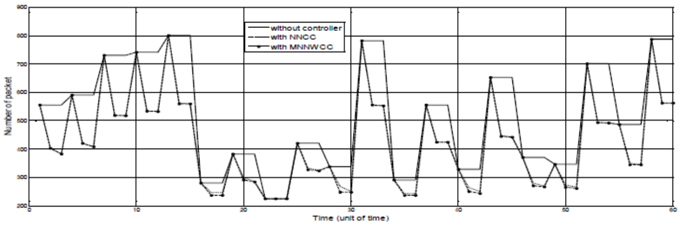


Figure 6: The number of packets arrives to the sink node

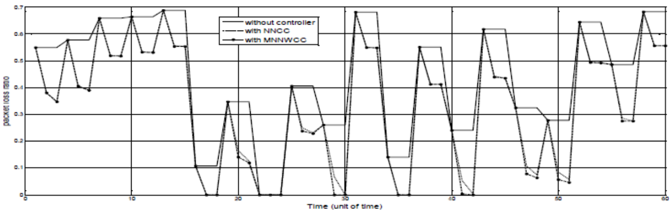


Figure 7: The packets Loss ratio

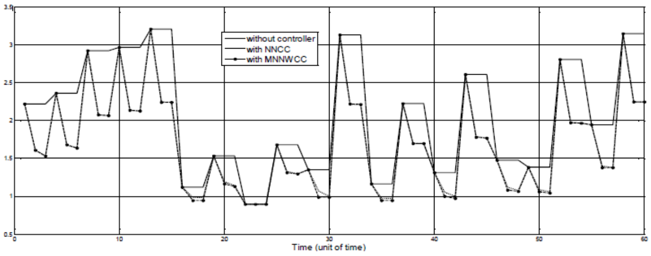


Figure 8: The Buffer Utilization

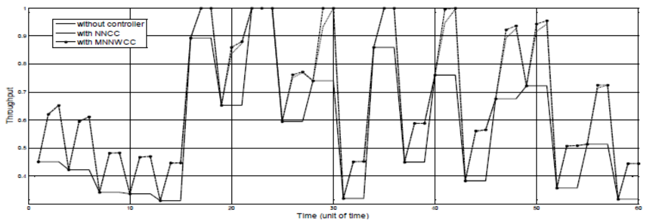


Figure 9: The Throughput

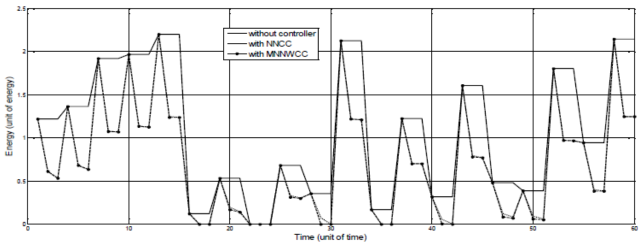


Figure 10: The Network energy

Conclusion

This paper proposed the modified approach based on modified neural network, this approach which is named as MNNWCC used modified wavelet as activation function in the hidden layer this help the controller to become more efficient than the standard neural network because the orthogonally feature of the wavelet. From the results one can conclude that the MNNWCC provides better QoS than the NN in terms of minimizing the PLR and improve BU, TP and NE.

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