A Novel TinyOS 2.x Routing Protocol with Load Balance Named CTP-TICN

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Abstract. Due to the limitation of power supply in wireless sensor nodes, the paper represented a new routing protocol which could be applied in TinyOS 2.x operating system named CTP-TICN. The new routing protocol realizes the preliminary achievement of load balance in wireless sensor network. CTP-TICN protocol introduces the “intensity of transmission” and “numbers of one hop up node” declaration, which could help nodes choose the suboptimal parent node for data forwarding on the premise of transmission stability. The simulation shows that CTP-TICN is more effective on load-balance than the CTP routing protocol and it helps the wireless sensor network to live for a longer time.

Keywords: CTP-TICN, TinyOS, Load Balance, Simulation in TOSSIM.

1 Introduction

Wireless sensor network is a kind of distributed computing network which consisted from large amount of nodes which integrate sensors, data processing units and short-distance communication models. It is a special Ad Hoc network and the application of WSN is widely spread in recent years.

Right now, the nodes in WSN network is mainly two series, one is MICA series and the other is TELOS series. These nodes usually supported by the battery, however, charging the battery is difficult in most situations. Thus, compared to the traditional wire network, the wireless sensor network routing protocol not only need to ensure the stability of transmission but also need to consider the living time of the whole network, avoiding some nodes deplete their battery too early because of burdened with a heavy transmission task[1].

With the development of new technology, there are many routing protocol presented in TinyOS 1.x and TinyOS 2.x, such as CTP(collection tree protocol), MultiHopLQI, MintRoute and so on[2]. The packets forwarding of these routing protocol are all based

Y. Wang and T. Li (Eds.): Knowledge Engineering and Management, AISC 123, pp. 3–9.
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on the judgment of link quality. Though the link quality mechanism could ensure the link free, it also let some of the parent node undertake more forwarding task. The result is that the battery of some parent node run down quickly and the living time of the entire network become short.

This passage introduces a CTP-TICN routing protocol after analysis the CTP routing protocol of TinyOS 2.x carefully. It can be applied in Mica and Telos series platforms and it has pragmatic value. CTP-TICN routing protocol introduces the “Intensity of Transmission” and “Numbers of One-hop before Child node” declaration which can control the data flow of parent nodes, realize the load balance of wireless sensor network. At the end of this passage, there exists the result of simulation and the vision for general direction of the WSN in the future.

2 CTP Routing Protocol Analysis

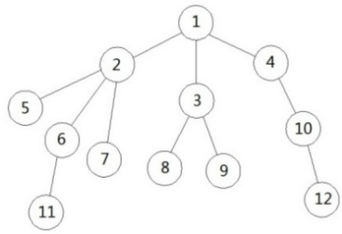
CTP is a normal multi-hop routing protocol. It has already been applied in real project. The basic idea of CTP is to construct a collection tree which regards gather node as its root. Nodes in network transmit information to the gather node through the tree. Every node maintains the bidirectional link quality evaluation of itself and its neighbors and sends data to the neighbors which have the best link quality. At this time, the neighbor becomes the node’s parent node[3].

CTP has two mechanisms to evaluate the link quality. The first one is based on the LEEP frame. The basic idea of LEEP frame protocol is the node collect information about the percentage of received broadcast package from its neighbor over the forwarding package sent to the neighbor by the node itself. For example, there are nodes α and β, $R\alpha$ represent the amount of package α received from β. $S\beta$ represent the amount of package β sent to α. In order so, the received link quality of α from β is: InQuality α-β= $R\alpha/S\beta$. So, the InQuality β-α= $R\beta/S\alpha$. As the result: OutQuality α-β= $R\beta/S\alpha$, OutQuality β-α= $Ra/S\beta$, InQuality α-β= OutQuality β-α, InQuality β-α= OutQuality α-β. The bidirectional link quality from α to β is represented by EETX (Extra Expected Transmission): EETX= InQuality α-β* OutQuality α-β.

The second method for evaluate the link quality in CTP is the evaluation based on the data package. The overall transmission packages between α and β is TotalData and the successful data package is SuccessData. The EETX= (TotalData/ SuccessData-1)*10 at this time. In order to reduce the evaluation flutter, the link estimator combines both methods above with exponential weighting, calculating the final link quality. The original EETXold is percentage 1-A, the EETXnew is percentage A. EETX= EETXold*(1-A) + EETXnew*A[4].

CTP uses ETX to represent the routing gradient. The root’s ETX is 0, other node’s ETX is its parent node’s ETX plus the EETX of the link quality to the parent node. The nodes broadcast information of routing state periodically, update the ETX of the route from its neighbor nodes to gather nodes. While the route table updated, the route engine choose the parent node depend on the minimum ETX value.

From the link quality evaluation mechanism and the route engine of CTP, we can find that CTP uses the link cost function to determine the relaying node and root node. So, it is impossible to avoid communication tasks on some special nodes, as the figure shows below:



Node 1 is the root node, because of node 2 burden with more reliable data transmission than other same level node such as node 3 and node 4. Node 2 will consume more energy than node 3 and node 4. The data message of node 2 is also easily to be congested. In order to solve such problem, in chapter 3, the paper put forward the CTP-TICN protocol to modulate the data flown dynamically. Thus, other same level nodes will share the data transmission of the "BUSY node" and balance the load of the network.

3 Idea and Realization of CTP-TICN

3.1 Network Model

CTP could be regarded as a collection tree with root node. Define model C (N, L, D), N represent the set of all nodes, L represents the set of all links, D represents the biggest hop between nodes and root. The$(i, j)^n$, i, j ∈ C represents the node j jump n times reach to node i[5].

1. Define the same level of nodes as: "SameLevelSet".
   SLSn= $\{j \mid \forall (ROOT, i)^n, j \in C, 1 \leqslant n \leqslant D\}$
2. Define the one hop up nodes as: "OneHopUpSet".
   OHUS= $\{ j \mid \forall j \in (i, j)^1, i, j \in C\}$
3. Define "intensity of data transmission" as: U= data flow/ parent node's data flow.
4. Define mean value of the intensity of data transmission among same level nodes: MVI.
5. Define mean value of number of child nodes among the same level nodes: MVN.
6. Define BE (Biggest ETX). BE is the maximum value of ETX value which could ensure the normal working.
7. Define the "BUSY node" state.

3.2 Description of Protocol CTP-TICN

CTP-TICN introduces the declaration of intensity of data transmission and the declaration of one hop up nodes. At first, every same level node "SLSn" broadcast the intensity of its own intensity of data transmission "U" and the number of one hop up nodes "OHUS". While all the intensity of data transmission and the number of one hop up nodes were collected, mean value such as “MVI” and “MVN” should be calculated. If the intensity of data transmission of one of the same level nodes exceeds the average intensity, the node would be remarked as “BUSY node”, if the nodes which had been remarked as “BUSY node” has less child nodes than the average amount among the same level nodes, the “BUSY node” avoiding mechanism wouldn’t be executed. If the nodes which had been remarked as “BUSY” has more child nodes than the average amount among the same level nodes, the “BUSY node” avoiding mechanism would be executed. One of the child nodes of this parent node would be chosen to avoid the “BUSY node”. While one of the parent nodes satisfied the avoiding condition above, the chosen of one of the child node as follows: 1) the value of U of the child node is the minimum of all the child nodes. 2) In the case of condition 1, BE $\geqslant$ ETX. The chosen of suboptimal parent node for the child nodes as follows: 1) BE $\geqslant$ ETX. 2) In the case of condition 1, the original intensity of data transmission of suboptimal parent node is the lowest of all the possible choices.

As the figure 1 shows below, node2, node 3 and node 4 are the same level nodes of level 1. First, in level 1, node 2, 3, 4 broad cast the intensity of their own intensity of data transmission “U” and the number of one hop up nodes “OHUS”. As figure 2 shows below, node 2 has a U=50% and OHUS= 3.

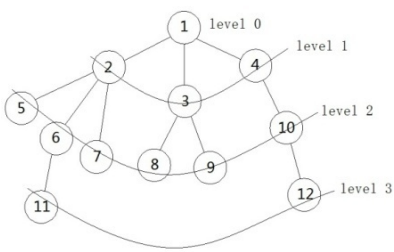


Fig. 1.

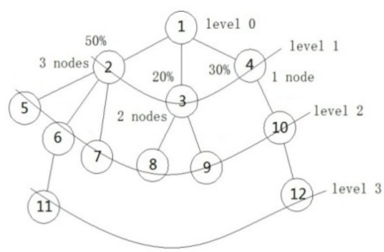


Fig. 2.

Thus, every level 1 node will know other nodes’ condition in level 1. At this time in level 1, mean value should be calculated. MVI= 33.3% and MVN= 2.

While node 2’s U > MVI, the node would be remarked as “BUSY node”, as figure 3 shows.

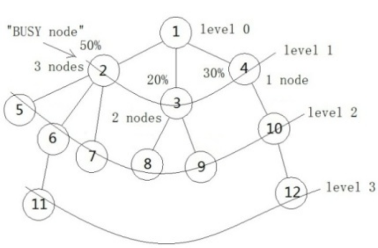


Fig. 3.

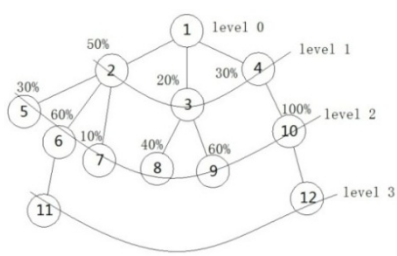
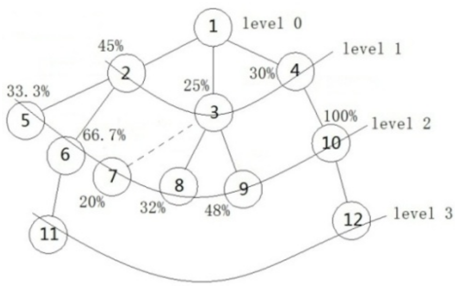


Fig. 4.

Also, the child node of node 2 > MVN, the “BUSY node” avoiding mechanism would be executed and one of the child nodes of this parent node would be chosen to avoid the "BUSY node". In level 2, the nodes are all the child nodes of the nodes in level 1. The value of U shows in figure 4.

Because of node 7 has the minimum U among node 5, node 6 and node 7, node 7 would be chosen as the alternative node to execute the avoiding mechanism. (Here we SUPPOSE that the link quality between node 3 and node 7, node 4 and node 7 are all satisfied the transmission requirement, which means BE $\leqslant$ ETX.)

Because of node 3 has the lowest transmission intensity in level 1. Thus, node 3 would be chosen as the suboptimal parent node for node 7. Finally, the topology of the net work shows below:



3.3 The Performance Evaluation Index of Load Balance for the Same Level Nodes

In order to judge the performance of the CTP-TICN protocol, we need to have an evaluation index for the load balance of the network. Thus, we put forward a new evaluation index named PEI-LB:

$$\text{PEI-LB}= \sqrt{\frac{\sum(\text{U}-\text{MVI})^2}{|\,\text{SLSn}\,|}}$$

From the formula we can find that PEI-LB means the standard deviation of the intensity of the data transmission in the same level. The more the PEI-LB close to 0, the better the network has load balance performance, vice versa.

4 Simulation

In order to test whether the idea of CTP-TICN protocol function well, there exist the need to simulate for this new protocol. Next, we will focus on the simulation of the CTP-TICN protocol. We still use the topology of the network in chapter 3, Figure 2. The SameLevelSet0 = {1}, SameLevelSet1 = {2, 3, 4}, SameLevelSet2 = {5, 6, 7, 8, 9, 10}, SameLevelSet3 = {11, 12}.

The simulation was finished in the TOSSIM[6,7] simulation platform. The type of the simulation nodes were chosen as Mica[9] Z wireless sensor node. Mica Z node uses ATMega128L as its central processing unit. The radio frequency chip of Mica Z was CC2420, it supports 802.15.4/Zigbee technology. Thus, no more telecommunication protocol was needed to develop. In software simulation, the nodes broadcast the routing protocol information to other nodes in the network every 7500ms. From the

TOSSIM flow information, the figure below shows the detailed information of the intensity of data transmission "U" in level 1. Every node has defined initial transmission intensity. At the beginning, Node2, Node3 and Node4 didn't know other nodes' information, it means the topology has not been formed and the three nodes only have their own data flow. So their transmission intensities are nearly the same. After a while, the topology began to form and the transmission intensity differs due to the EETX of the link quality. In this condition, the CTP protocol needs almost 30 second to form the topology in 3 levels. The simulation of CTP protocol shows below:

CTP Routing Protocol

Node ID / Times	Node2's U	Node3's U	Node4's U	SUM of U
7500ms	35%	33%	32%	100%
15000ms	39%	29%	32%	100%
22500ms	44%	25%	31%	100%
30000ms	49.5%	20%	30.5%	100%
37500ms	49.5%	20.5%	30%	100%
Stable	50%	21%	29%	100%
Stable	49.5%	20.5%	30%	100%

The table below shows the information of CTP-TICN protocol in simulation. CTP-TICN routing protocol need more time in topology.

CTP-TICN Routing Protocol

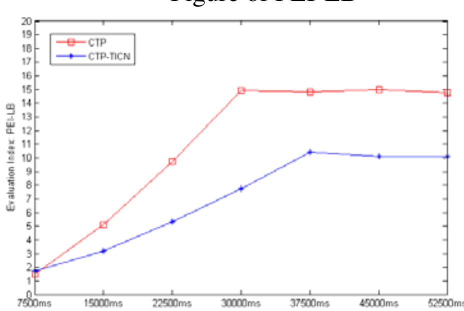
Node ID / Times	Node2's U	Node3's U	Node4's U	SUM of U
7500ms	35%	33.5%	31.5%	100%
15000ms	37%	32%	31%	100%
22500ms	39.5%	30.5%	30%	100%
30000ms	42%	27%	31%	100%
37500ms	45%	25%	30%	100%
45000ms	45%	25.5%	30.5%	100%
Stable	44.5%	25%	30.5%	100%

Table & figure below shows the difference of PEI-LB between CTP and CTP-TICN.

Value of PEI-LB

PEI-LB / Times	PEI-LB for CTP	PEI-LB for CTP-TICN
7500ms	1.53	1.76
15000ms	5.13	3.21
22500ms	9.71	5.35
30000ms	14.95	7.77
37500ms	14.8	10.41
45000ms	14.98	10.13
52500ms	14.78	10.1

Figure of PEI-LB



Obviously, the CTP-TICN has less evaluation index for the load balance, which means the CTP-TICN routing protocol has a better ability to balance the load of the network and the energy consumption is more equilibrium than the CTP routing protocol.

5 Ending

In the network, especially the wireless sensor network, huge quantity of aspects in routing protocol needed to be discussed carefully. This passage introduces a new TinyOS 2.x routing protocol named CTP-TICN which had already achieved the preliminary success in load balance for the WSN system. The "intensity of transmission" and "numbers of one hop up node" are put forward after consideration carefully. The simulation shows that these mechanisms solve the load balance in WSN system successfully and the PEI-LB evaluation index could present the degree of load balance in network perfectly. However, there still exist some problems in CTP-TICN. Introducing the load balance mechanism into the network system means the nodes must waste more resources in arithmetic for the routing selection, also, the function of the CTP-TICN is still limited because of its judging condition. Sometimes there exists better topology for the entire network in load balance. These problems are the tendency of further discussion and research.

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