Collect Tree Protocol for SHM System using Wireless Sensor Networks

Amira Zrelli
Communication System Laboratory Sys'Com,
National engineering School of Tunis,
University Tunis El Manar, Tunisia
Amira.zrelli@enit.rnu.tn

Tahar Ezzedine
Communication System Laboratory Sys'Com,
National engineering School of Tunis, University
Tunis El Manar, Tunisia
Tahar.ezzedine@enit.rnu.tn

Abstract—**Routing protocol may enhance the lifetime of sensor network, it has a highly importance, especially in wireless sensor network (WSN). Therefore routing protocol have a big effect in these networks, thus the choice of routing protocol must be studied before setting up our network. In this work, we implement the routing protocol CTP (collect tree protocol) which is one of the hierarchic protocols used in structural health monitoring (SHM).Therefore, to evaluate the performance of this protocol, we choice to work with contiki system and cooja simulator. By throughput and RSSI evaluation of each node we will deduce about the utility of CTP in structural monitoring system.**

***Index Terms*—Collect Tree Protocol, WSN, SHM, routing protocol, RSSI, throughput.**

I. Introduction

To enhance the lifetime of wireless sensor network (wsn), energy present an important parameter, so the energy residual of each nodes can easily involve the performance of sensor networks [8]. Wsn has been nowadays exploited in many topics and domains, for our case we are interested in the structural health monitoring. The primary function of Structural Heath Monitoring (SHM) is the intelligent monitoring of any type of applied load (stress, strain) or whatever parameters like temperature, humidity, pressure, gas, etc. SHM is defined as continuous and autonomous control of structural damage. We are talking about "smart structures" which are able to exercise self-assessing of the structural integrity. When we use the new technology SHM, we can control many physical phenomena such as water level, pressure or luminosity, etc. Therefore, SHM resorts to optical sensors to control different parameters, these sensors measure some properties of the light that is launched by a source into the core of the fiber [5] [6].Yet, installation of wired sensors is very expensive, especially in tunnels, mines and existing buildings, whereas wireless sensors are inexpensive and easily deployable. By choosing the optimal placement of sensor in civil structural, we can optimize energies consummations. The primary objectives of almost every node placement technique are to ensure that the entire structure is covered. For at least half a century, various and different forms of SHM have been used in civil infrastructure, although it is only in the last decade or two that SHM systems have been designed for several type of structures (tunnels, bridges, buildings, dams, etc). The purpose aim of SHM system is to monitor infrastructure with timely information for their continued safe and economic operation [7].Thus, in civil engineering, the monitoring of the structural state of various civil structures is essential insofar as the safety of the structures is essential for the proper functioning of a civil structure. To check for any anomalies in the structure, several measurements have to be made in different strategic areas of the structure. Different mechanical parameters such as displacements, deformations, accelerations and thermal parameters such as temperature and humidity must be closely and strictly monitored in SHM systems [5]. By securing civilian infrastructure, the aim is first and foremost to satisfy the conditions of the life insurance of persons, from which the ministries of equipment of the different countries of the world, consider that the inspection and the continuous control of the structures Civil works (city structures, civil buildings, bridges and roads, tunnels, motorways etc.) as their first concerns. Traditional instrumentation systems for civil engineering structures have traditionally used coaxial cables to ensure the routing of data from the installed sensors to the base station, which is usually centralized, or they will always be stored For possible analysis and interpretation. This technique of control of the structures not only generates a high cost of the instrumentation systems cables due to the length of the coaxial cables used, but also conditions a very large number of sensors to use. Recently, the appearance of the SHM has responded to the problems of the old solution monitoring.

II. Structural Health Monitoring and WSN

A surveillance system is designed to monitor and detect damage or intrusion or attempted intrusion as soon as possible in order to secure the human being by implementing alarms. These alarms are numerous, namely, audible alarms, light alarms such as blinking, the use of red lamps, etc. Two main monitoring systems exist: the first system, the wired alarm, and the second, it is a wireless alarm system. In SHM system based on WSN, routing protocols must ensure reliable transfer of data and maintain connectivity between different nodes. Nevertheless, there are several routing protocols that can’t be adopted for SHM monitoring structures due to traffic such as que DSDV (Destination Sequenced Distance Vecteur), TORA (Temporally-Ordered Routing Algorithm), DSR (Dynamic Source Routing), etc. Thus, a great need to develop routing protocols specially dedicated to SHM systems. We can adopt for these systems either hierarchical routing protocols such as CTP (Collection Tree Protocol) which has been implemented in our work to assess and to evaluate its performances.

A. SHM

By definition, the main function of Structural Heath Monitoring (SHM) is to provide intelligent monitoring and continuous, autonomous control of damage to the structure and any other type of loading applied (stresses and deformations). We are talking here of "intelligent structures" capable of self-monitoring by evaluating their structural integrity. The use of SHM meets the need to control many physical phenomena such as temperature, humidity, vibration, pressure or brightness.

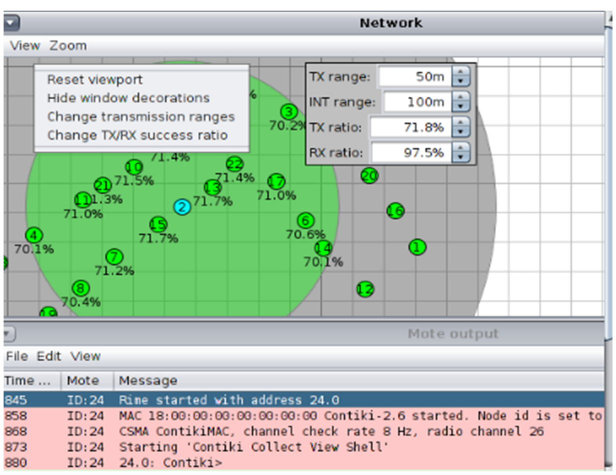

Fig 1. Example of node deployment under contiki system

B. WSN

SHM systems based on wireless sensor networks have been extensively studied, in addition to numerous experimental results have been presented in the literature. However, none of the previous studies presented a global model and a complete architecture of a wireless SHM system. A wireless network consists of a base station, a set of relays, sensors and attached nodes.

C. SHM based on WSN

Wireless sensor networks are widespread in the monitoring of various civil engineering infrastructures. This type of monitoring, based on wsn, is not frequently investigated in scientific publications [1]. WSN are based on standard protocols for wireless sensor networks, but with features that enhance service quality and safety. The capabilities of wireless links are used in the monitoring of civilian structures due to the low number of jumps in these networks. In reality, WSN’ nodes may have failures that affect the quality of monitoring systems, whereas to ensure good supervision of the structures, it is necessary to make the best choice of routing protocol [1].

III. Collect TREE PROTOCOL

Hierarchical routing protocols are more favorable and adequate for SHM systems. We have thus chosen to implement in the nodes the CTP collection routing protocol which is a hierarchical protocol, in addition this protocol can work with many of the nodes while consuming the minimum of energy. It is then very beneficial to apply the CTP protocol in the field of structural monitoring since it is very easy to implement in the nodes and consumes the minimum energy.

A. Routing Protocol for WSN

Routing protocols in WSNs are a fundamental part to guarantee and assure the success and the effectiveness of the target application as well as the quality of monitoring system.

An SHM system must ensure the detection and monitoring of its environment. It must also guarantee the transmission of the data it receives from the sensors and relays to the base stations. Indeed, the sensors generate data packets periodically. These packets are of the same size, whereas it is necessary to adapt an adequate routing protocol.

B. Architecture of CTP

As we know the CTP protocol relies heavily on sharing data between neighboring nodes through routing packets to build and maintain the routing topology. We chose to work with the operating system "Contiki" as it is simple to implement protocols with this system. The data is sent via a tree topology to a receiving node [2](see figure 2). CTP is based on the ETX metric (expected number of transmission). In fact, ETX reduces the number of data packets and estimates the number of transmissions required to send a packet to a single destination. In WSN, ETX represents a routing metric that considers as a highly variable link quality for a specific radio The ETX metric is calculated by the following equation:

$$\mathrm{ETX}(a,b) = \frac{1}{(D_{ab} + D_{ba})} = \frac{1}{\mathrm{PRR}_{\mathrm{forward}} + \mathrm{PRR}_{\mathrm{background}}} \tag{1}$$

D_{ab}: Probability of success of a transmission $a \rightarrow b$

D_{ba} : Probability of success of a transmission $b \rightarrow a$

If an ACK packet comes from a new node for the first time to the node in question (the one of interest), then automatically add the value of its ETX within the table called ETX History containing the different old values Of ETX. On the other hand, if the ACK packet comes from a node already existing in our table we add the value of ETX to the old value [4].

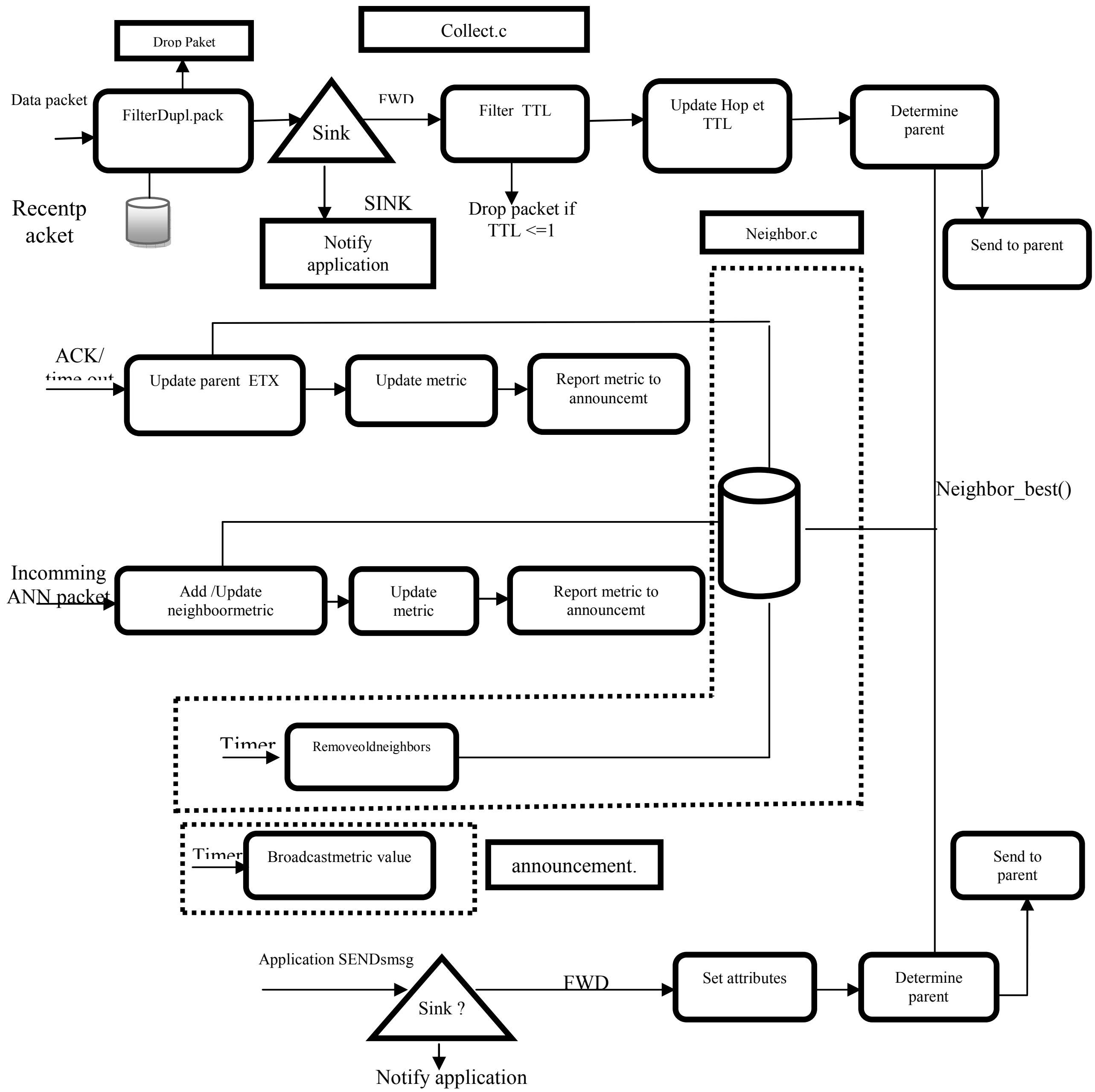

Fig 2. Architecture of CTP under Contiki

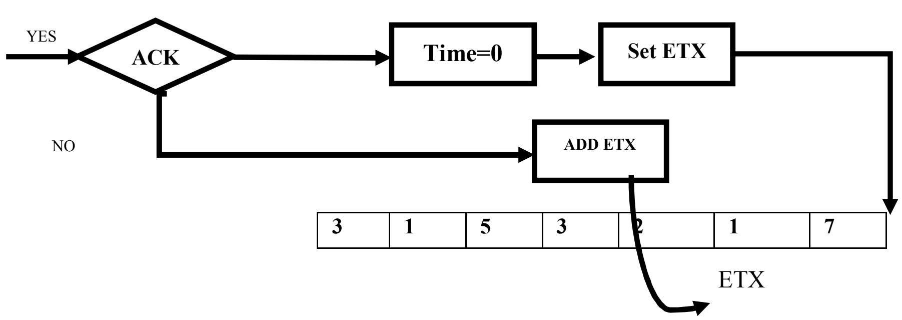

Fig 3.The contiki collect protocol: ETX History

C. CTP under Contiki

The routing protocol CTP is implemented under Contiki system thanks to the characteristics and components of this operating system. Figure 2 illustrates the response of CTP protocol to different events: an incoming data packet, an acknowledgment or delay of a sent data packet, an incoming packet call, etc. When we implement this protocol we take care about all these events.

Contiki is an open-source multi-tasking operating system for microcontrollers with small amounts of memory, such as wireless sensor networks. A typical Contiki configuration is 2 kbytes of RAM and 40 kbytes of ROM. Contiki is written in the C programming language and has been developed at the Swedish Institute of Informatics since about 2004. It is similar to TinyOS, another well-known open-source operating system that targets the WSN.

IV. Performance of CTP

In order to adopt the CTP protocol to the SHM systems, it is essential to estimate and to know the distances between the nodes, more precisely between a node and a base station. The preliminary tests presented below make it possible to extract the most appropriate values from the parameters, which considerably affect our system. We choose to interpret the following two metrics: the packet transmission rate and the received signal strength indicator unchangeable over time. The following figure represents the deployment of these motes:

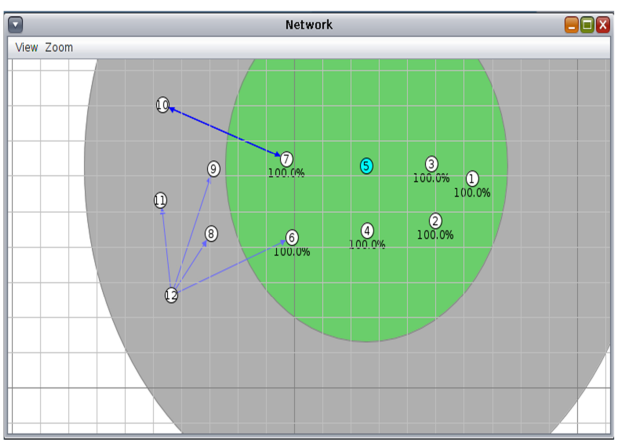

Fig 4. Sensor network with CTP routing protocol

A. Throughput

By measuring the throughput in our network, we aim to study the relation between nodes placement and throughput. This parameter is calculated from the following ratio:

$$D = \frac{Total\ Packet\ received}{Time\ of\ simulation \times Number\ of\ nodes} \tag{2}$$

We choose to present the flow of nodes 5, 14, 1, 13 and 11, this graph confirm the pervious equation (2).

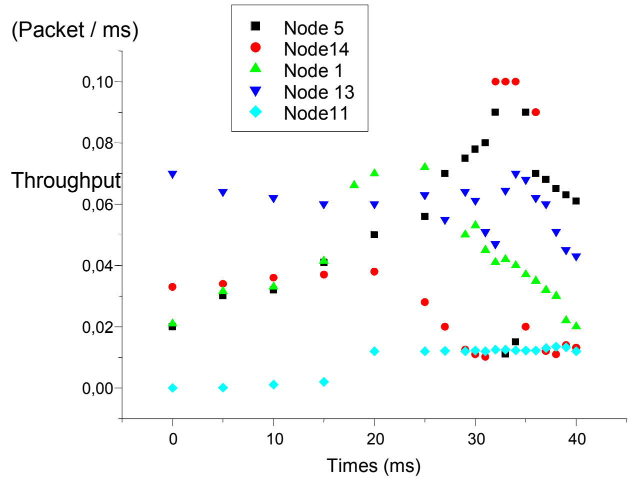

Fig .5 Throughput of node 11,13, 1, 14 and 5

B. RSSI

Received Signal Strength Indication (RSSI) provides a measure of received signal power, it give a reliable indication of received signal strength. Generally, the significance of this measure is expressed in a logarithmic scale (often in dB which is compared to 1 mW). The RSSI is expressed by the following equation:

$$RSSI(dB) = 10\log(\frac{P_t}{P_r}) \tag{2}$$

Where P_t Power of transmitted signal
P_r Power of received signal

$$P_r = P_t\,(^1/_d)^n \tag{3}$$

d is the distance between the sending and receiving nodes and n is the transmission factor whose value depends on the propagation environment [3].

$$RSSI(dB) = 10\log(\frac{P_t}{P_t.\left(\frac{1}{d}\right)^n}) = 10\log(\frac{1}{\left(\frac{1}{d}\right)^n}) \tag{4}$$

We study the SHM systems where the wireless network used is fixed (not mobile) so it should be noted that the distance between the sink and the node transmitting the data remains unchangeable over time. Thus, in our case the RSSI strongly depends on the transmission factor n. This factor is greatly affected by the propagation medium of the sensors plus the node is placed away from the base station (sink) the more difficult it will be during emission, the signal strength will be attenuated and consequently the RSSI decreases.

We have also chosen to present the RSSI of these two other nodes. In effect, RSSI represents a measure of the reception power of a received signal. The RSSI is used to provide an indication of the intensity of the received signal.

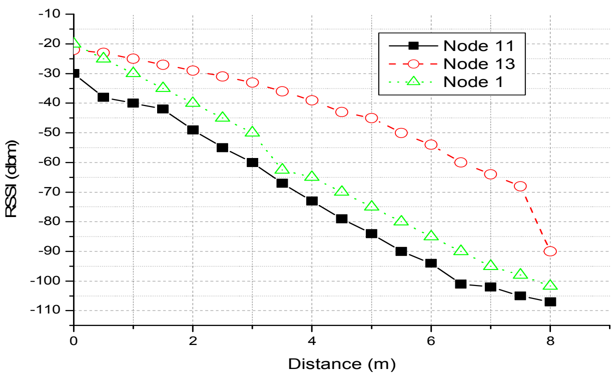

Fig 6. RSSI of node 11, 13 and 1

It is clear that the RSSI values depend on the positioning of the nodes, it can be noted that the node value N5 which within the scope of the sink (node 1) and this distance is the foundation and the scope key and positioning technologies. The change of position of the nodes 5 and 8 leads to the change of the RSSI values.

CONCLUSION

When we use wsn to monitor civil structures, we need to implement a suitable routing protocol in this work, CTP had been evaluated. So, in this paper, we present a simple architecture of collect tree protocol; we highlight the effect of distance on RSSI and throughput. RSSI values depend on the node deployment, throughput depend on distance between sink node and mote, time simulation and number of nodes. To realize a SHM system based on wsn, we can deduce that in the case of huge and vast civil structures this algorithm will not be able to route data packet: RSSI decreases sharply at a distance near to 8m, also we can deduce that the ideal placement of nodes in CTP is to be near the sink node.

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