A Forwarding Station Integrated the Non-Confirmed Routing Protocol in Ad-hoc Wireless Sensor Networks

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Abstract: - An ad-hoc wireless sensor network organizes itself as a network that many sensor nodes automatically communicate each other in a certain area. Each sensor node consists of a transmitting unit, receiving unit, central processing unit, and battery unit. Because of the sensor node's battery unit that may not be reachable or rechargeable, it is important for both the base station and sensor nodes communicating very well for less energy consumption of sensor nodes to extend the entire ad-hoc wireless sensor network lifetime. Moreover, in this paper, the ad-hoc wireless sensor network is divided into many clusters and every cluster contains only one cluster head. All wireless sensor nodes will transmit their messages to the cluster head where they belong to. Then, the cluster head will return a confirmed message back to every sensor. However, it dissipates much energy to retransmit a confirmed message from the cluster head to the sensor node. Since the base station is far away from the sensed area, it is necessary to have a forwarding station forwarding the message from the sensed area to the base station. Finally, this paper proposes the forwarding station integrated the non-confirmed routing protocol so that the network lifetime can be extended very well. Also, simulation results show the network lifetime extended well and the performance is much better.

Key-Words: - Energy consumption, Network lifetime, Ad-hoc wireless sensor networks, Confirmed message, Forwarding station, Routing protocol.

1 Introduction

In recent years, the better technologies [1-3] bring with the better performance solution such as nanotech-chip design, small tiny embedded OS, faster data processing with the lower power chip, and longer lifetime battery. With these hardware improvements, the entire wireless sensor network lifetime can be extended very well. However, a wireless sensor network consists of many sensor nodes that each sensor node is composed of the transmitting unit, the receiving unit, the central processing unit, and the battery unit. The architecture of a sensor node is shown in Fig. 1.

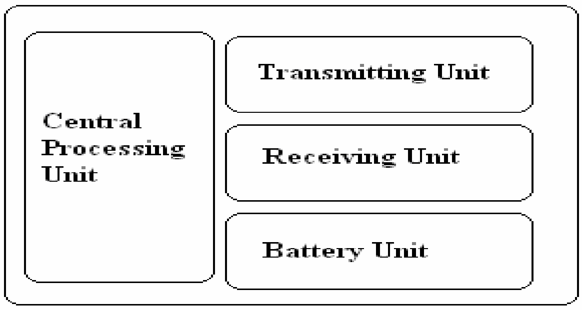

Fig. 1: Architecture of each sensor node.

Fig. 1 depicts that each sensor node contains a transmitting unit which consumes the most energy to transmit a message. That is a transmitting unit needs an amplifier unit to transmit messages. The energy of the transmitting unit consumes the energy depending on the distance of the transmitting unit transmitted a message. Therefore, the longer distance a sensor node transmits the more energy it consumes.

Because of the technology of wireless, the digital messages of each sensor node can be delivered to anywhere. Therefore, many possible solutions can be done [4] such as temperature and hurricane monitored, medical analysis, military, chemical environment and so on. For example, a certain sensing area contains as many sensor nodes as possible. These sensor nodes can automatically monitor unreachable environments. Before making any decision of those unreachable environments, the entire ad-hoc wireless sensor network can gather all information and put it into analysis.

In general, the technology of direct transmission [5] [6] is that the sensor node can transmit the message directly back to the base station (B.S.).

This will consume the most energy but it is the better way to transmit the message back to base station. In another word, the response time to the message delivered back to the base station is the best. The worse case is the distance's problem which uses the energy much. Therefore, the technology of multi-hop is especially used for sensor nodes not to transmit a message too far. That is the multi-hop is the sensor node sending messages to the closer sensing node.

Moreover, compared to both direct transmission technology and multi-hop technology, the low energy adaptive clustering hierarchy (LEACH) [9] has better performance. LEACH uses random cluster head with the probability in order to extend the entire networking lifetime. Papers [10-12] are also discussed the LEACH protocol that a sensing area is divided into many small areas whereas every small area contains only one cluster head. Every sensor node transmits its message to the closer cluster head and the cluster head will directly send the message back to the base station. However, the architecture of LEACH uses two phases for the entire wireless sensor network in order to make the performance better. First, the setup phase is to pick up one of sensor nodes as a cluster head for each cluster in each round. Also, the setup phase is one of the sensor nodes in each cluster will be randomly chosen as a cluster head with pre-determined parameter *p*. Therefore, each sensor node closer to the cluster head belongs to that cluster. Second, the transmission phase is the message of each sensor node transmitted to the cluster head and then the cluster head will send the message directly back to the base station. This, the architecture of LEACH, can use the less energy consumption because of the random and probability method. In order to have the sensed data back to base station, the technology of wireless and networking are reasonable applied [13]. Therefore, energy consumption [14-16] is an important issue.

Furthermore, the confirmed message can ensure whether or not the message can be transmitted back to the base station during the transmission phase. Therefore, the confirmed message and non-confirmed message [24] are discussed in this paper with a forwarding station (F.S.) or no forwarding station. By the proposed scheme, a forwarding station integrated with the non-confirmed routing protocol not only can it extend the network lifetime, but also can it have the fastest response time. However, every sensor node transmitted message for each other all the time consumes energy very much [7]. Thus, every sensor node should save as much energy [8] as possible for exchanging data.

2 Network Model

Fig. 1 shows each sensor node consists of a transmitting unit, receiving unit, central processing unit and battery unit. With the limited battery unit, the most dissipated energy is from the transmitting unit in which the transmitting unit needs an amplifier to transmit messages of sensor nodes. The transmitting unit consumes the energy depending on the distance. The more distance a sensor node transmits, the more energy a sensor node dissipates. Moreover, the dissipating energy of receiving unit [17-20] depends on the total amounts of message that sensor nodes receive.

The energy consumption, E_{TX}, to transmit a message from one node to another node is expressed by

$$E_{TX} = l \cdot E_{elec} + l \cdot \varepsilon_{fs} d_{toCH}^2 , \qquad (1)$$

where l represents a message (bits) communicated between two sensor nodes. Assumption of free space d^2 is used. ε_{fs} represents an amplified transmitting energy in free space.

The energy consumption, E_{RX}, to receive the message from one node to another node is expressed by

$$E_{RX} = l \cdot E_{elec} . \qquad (2)$$

Simulation parameters used in this paper are in the table 1 as shown below.

Table 1: Parameters usages

Notation	Description
E_o = 0.5J/bit	Initial energy of every node
E_{elec} = 50nJ/bit	Energy consumption of per bit
E_{DA} = 5nJ/bit	Energy of data aggregation
ε_{fs} = 10pJ/bit/m^2	Energy in a free space
d_{toCH}^4	Energy in a multi-path environment
d_{toCH}^2	Energy in free space environment

Forwarding Station	Unlimited energy

In general, as a sensor node *A* transmits a message to another sensor node *B*, *B* will transmit a confirmed message back to *A* in order to make sure whether or not *B* has received the message already. The dissipated energy of a sensor node *A* to transmit the energy is E_{TX}. Similarly, the dissipated energy of a sensor node *B* to receive the energy is E_{RX}. Therefore, as a sensor node transmits a message, it will also receive a confirmed message. However, the total amount of dissipated energy of a sensor node to send a message is expressed by

$$\begin{aligned} E_{Ack\_Node} &= E_{TX} + E_{RX} \\ &= l \cdot E_{elec} + l \cdot \varepsilon_{fs} d_{toCH}^2 + l \cdot E_{elec} \\ &= 2 * l \cdot E_{elec} + l \cdot \varepsilon_{fs} d_{toCH}^2 . \end{aligned} \quad (3)$$

In fact, the amounts of the confirmed message are less than the original transmitted message in reality. However, suppose one of sensor nodes is failed or inactive, other sensor nodes sending the message to this sensor node will keep sending message until sensor nodes run out of their energies. Therefore, sensor nodes can transmit their messages directly to other sensor nodes with non-confirmed message. With the non-confirmed message, each sensor node directly transmits the message to the cluster head and then forwards the message directly back to the base station. This will not consume the energy of the confirmed message and; therefore, the network lifetime can be extended very well. The consumed energy with non-confirmed message is expressed by

$$E_{NACK\_Node} = l \cdot E_{elec} + l \cdot \varepsilon_{fs} d_{toCH}^2 . \quad (4)$$

As *n* nodes are in a cluster, every sensor node will transmit their messages to the cluster head where they belong to and the cluster head consumes the energy is given by

$$E_{Total\_CH} = n \cdot l \cdot E_{elec} . \quad (5)$$

As the cluster head receives the data from each node, the confirmed message is no need to transmit it back right away. The consumed energy [23] from the cluster head to all its member nodes is expressed by

$$E_{OptCHMember} = l \cdot E_{elec} + l \cdot \varepsilon_{fs} d_{Max\_toCH}^2 . \quad (6)$$

3 A Forwarding Station Integrated with the Non-Confirmed Routing Protocol Model

In the Ad-hoc wireless sensor networks, two phases are set-up phase and transmission phase. First, the setup phase is that a wireless sensor network is divided into many clusters and each cluster contains only one cluster head. Second, the transmission phase, each sensor node transmits the message to the cluster head where it belongs and then the cluster head will forward the message back to the base station [21] [22].

In Fig. 2, sensor nodes are randomly deployed so that *N1*, *N2*, *N3* and so on represent sensor nodes. Suppose that *N1* transmits a message called *T1* to the cluster head. The cluster head has a confirmed message called *Ack1* back to the sensor node to make sure whether or not the cluster head has received the message form *N1*. However, there are *N* sensor nodes in a cluster and suppose each sensor node will transmit a message to the cluster head. There will be totally *N* confirmed messages back to sensor nodes.

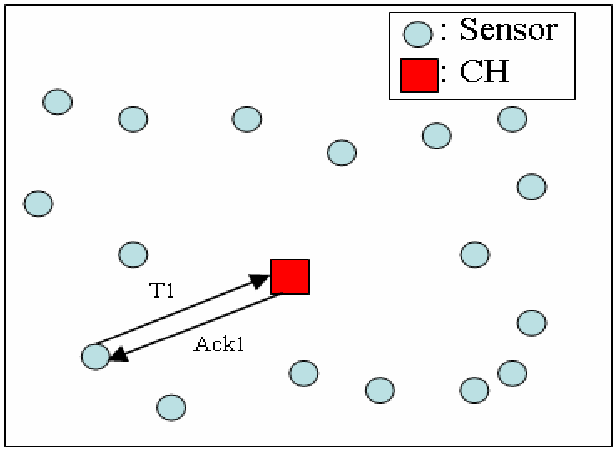

Fig. 2: Confirmed message by the cluster head.

Extending the network lifetime, the cluster head only needs to transmit a single message which is longest distance to all sensor nodes as shown in Fig. 3. The cluster head can send a message called *Ack_L* which has the longest distance. Therefore, all sensor nodes of a cluster will be covered by the signal (*Ack_L*).

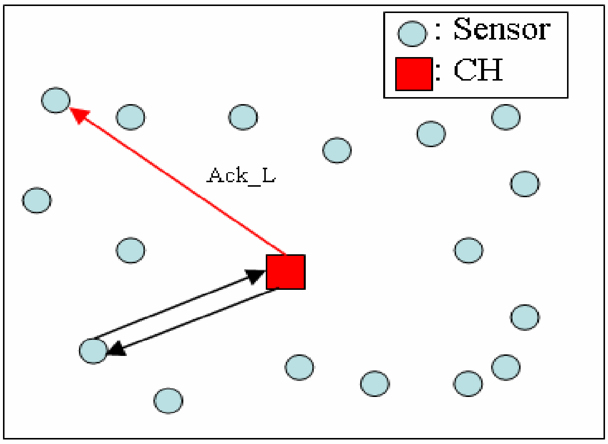

Fig. 3: *Ack_L*, the longest distance in a cluster.

In order to save energy and extend the network lifetime, a forwarding station integrated with non-confirmed routing protocol is proposed in this paper that is sensor nodes transmit the data to the cluster head with the non-confirmed message from the cluster head in the transmission phase as shown in Fig. 4. Therefore, the confirmed message (*Ack1*) is no more need. That means all sensor nodes transmit the message to the cluster head and then forward it directly to forwarding station which will send all messages back to the base station.

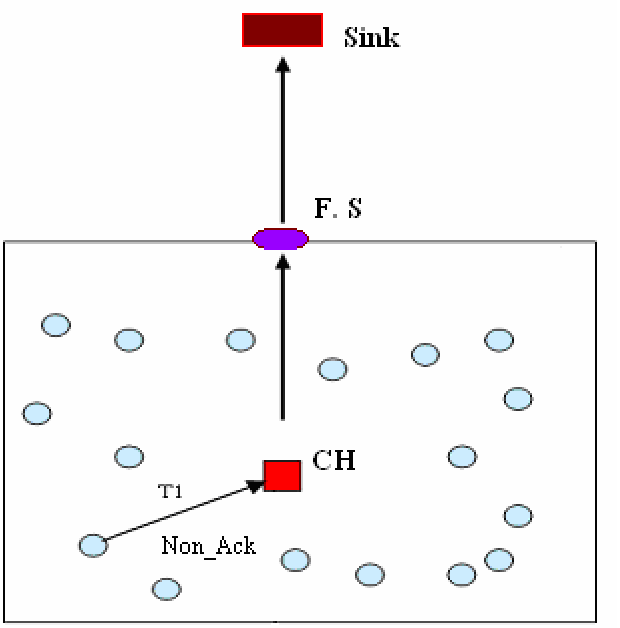

Fig. 4: Sensor node sends a message to the F.S. with non-confirmed message.

4 Simulation results

In this paper, there are totally 100 sensor nodes randomly deployed into 100 m x 100 m as shown in Fig. 5 where the base station is at the point (50, 175) with the confirmed message. The simulation tool is Matlab. In Fig. 6, as the base station is at (50,175) with the confirmed message, clusters are formed. In Fig. 7, as the base station is at (50,175) with the confirmed message, the result is at 600 rounds. In Fig. 8, as the base station is at (50,175) with the confirmed message, the result is at 1200 rounds. Fig. 5-8 show the cluster formation and how many sensor nodes are still alive there. Here, "o" stands for a sensor node is still alive. "." stands for a sensor node is no longer alive. "+" stands for a cluster head. "*" stands for the base station.

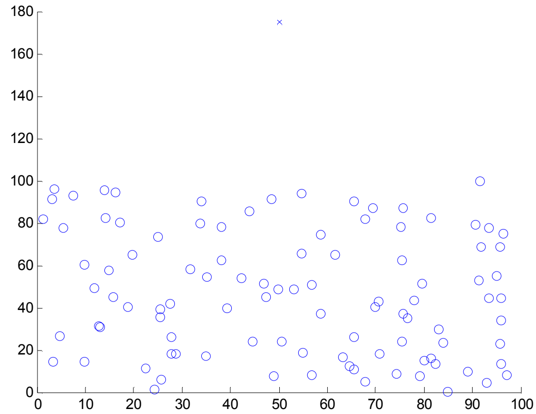

Fig. 5: 100 nodes and B.S. (50,175) with the confirmed message.

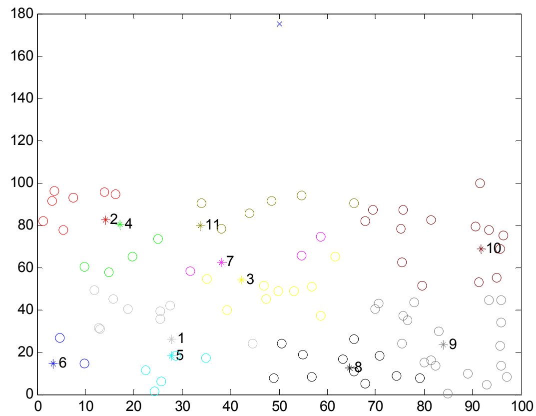

Fig. 6: B.S. (50,175) with the confirmed message and clusters are formed.

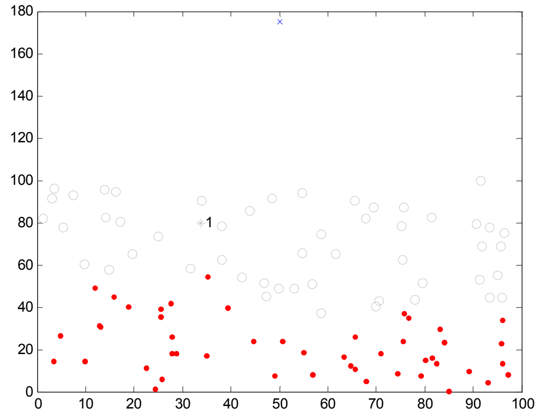

Fig. 7: B.S. (50,175) with the confirmed message in 600 rounds.

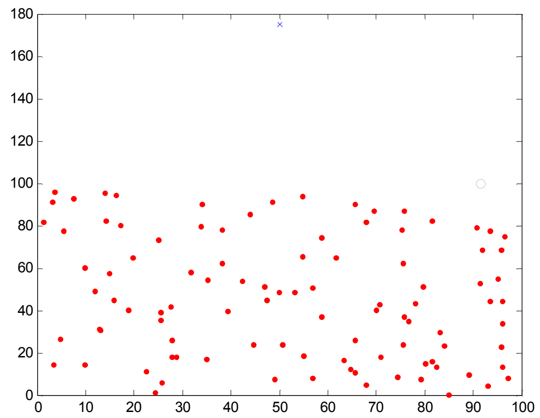

Fig. 8: B.S. (50,175) with the confirmed message in 1200 rounds.

Fig. 9 reveals that the base station is at the point (50,175) with the confirmed message and the forwarding station is at the point (50,100). Fig. 10 shows clusters are formed. Fig. 11 shows the result is after running 600 rounds and Fig. 12 shows the result is after running 1200 rounds.

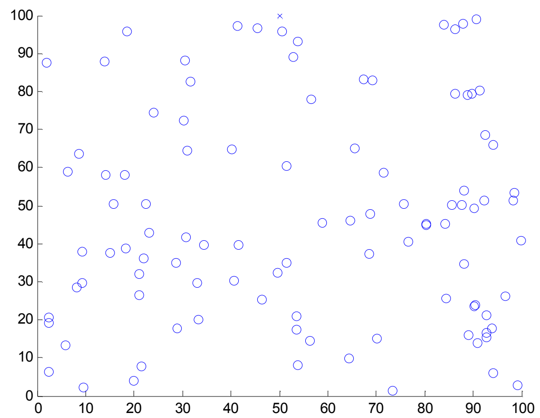

Fig. 9: 100 nodes, B.S. (50,100) and F.S. (50,100) with the confirmed message.

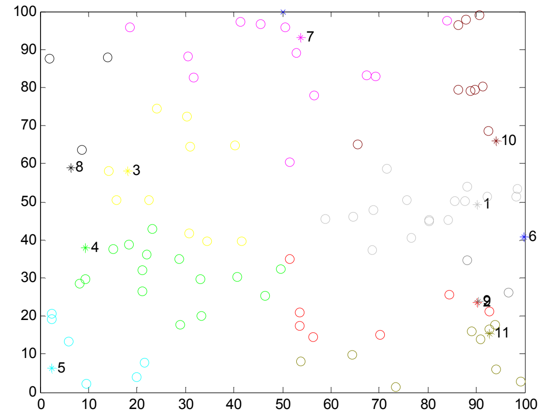

Fig. 10: B.S. (50,175), F.S.(50,100) with the confirmed message, clusters are formed.

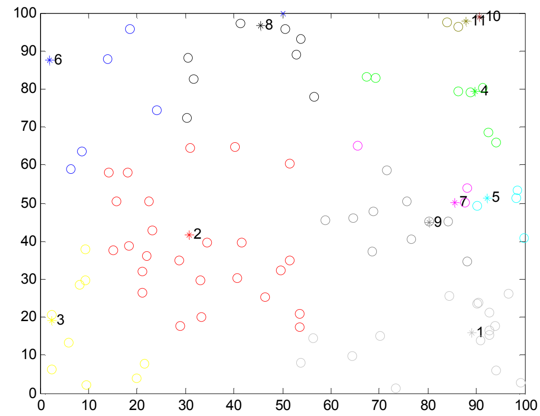

Fig. 11: B.S. (50,175), F.S. (50,100) with the confirmed message in 600 rounds.

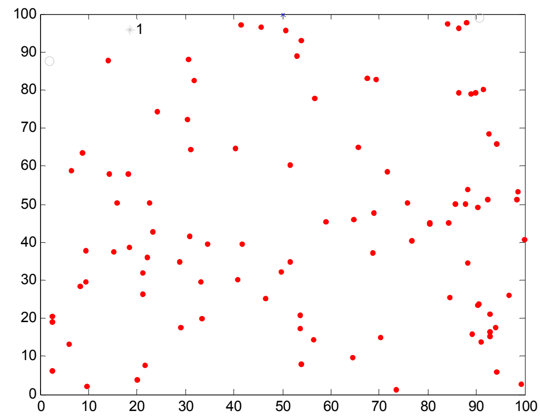

Fig. 12: B.S. (50,175), F.S. (50,100) with the confirmed message in 1200 rounds.

Fig. 13 shows that 100 nodes are randomly deployed as the base station is at point (50,175) with the non-confirmed message. Fig. 14 shows as the base station (50,175) is with the forwarding station (50,100) integrated the non-confirmed message, clusters are formed. Fig. 15 shows that the result is running after 600 rounds. Fig. 16 shows that the result is running after at 1200 rounds.

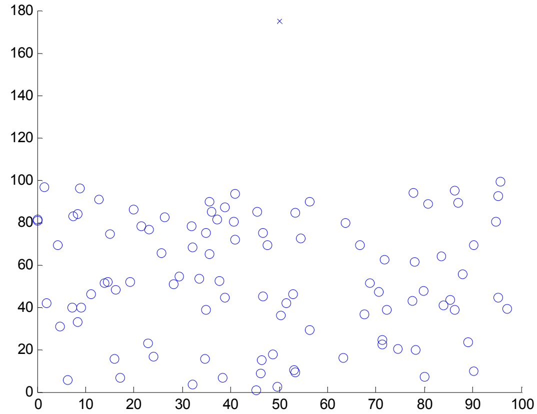

Fig. 13: 100 sensor nodes and B.S. (50,175) with the non-confirmed message.

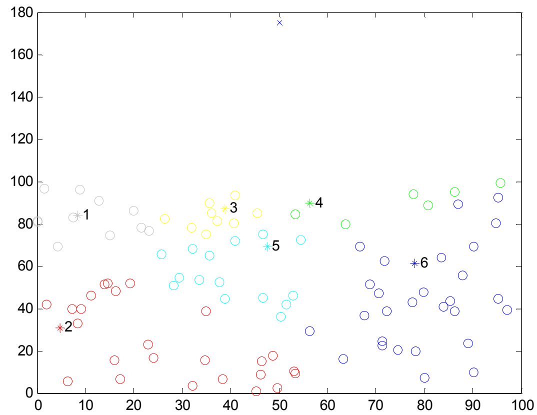

Fig. 14: B.S. (50,175), F.S. (50,100) with the non-confirmed message, clusters are formed.

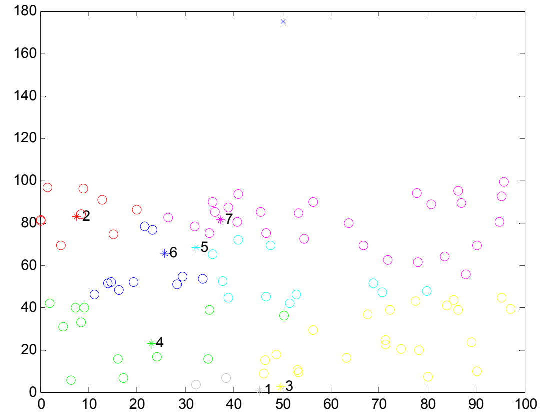

Fig. 15: B.S.(50,175) with the non-confirmed message after 600 rounds.

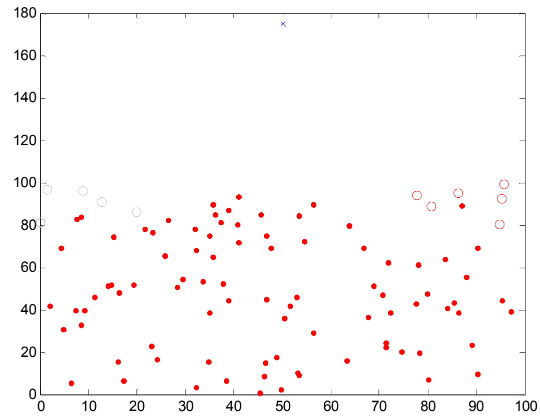

Fig. 16: B.S. (50,175) with the non-confirmed message after 1200 rounds.

Fig. 17 shows that 100 nodes are randomly deployed as the base station is at point (50,175) with a forwarding station at point (50,100) integrated non-confirmed message. Fig. 18 shows as the base station is at point (50, 175) with the forwarding station at (50,100) integrated with the non-confirmed message, clusters are formed. Fig. 20 shows as the base station is at (50, 175) forwarding station is at (50,100) with the non-confirmed message, the result is at 1200 rounds. Fig. 20 shows as the base station is at (50, 175) forwarding station is at (50,100) with the non-confirmed message, the result is at 1200 rounds.

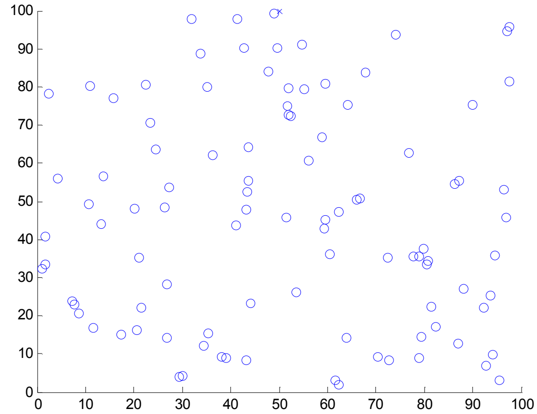

Fig. 17: 100 nodes, B.S.(50,175) and F.S (50,100) integrated non-confirmed message.

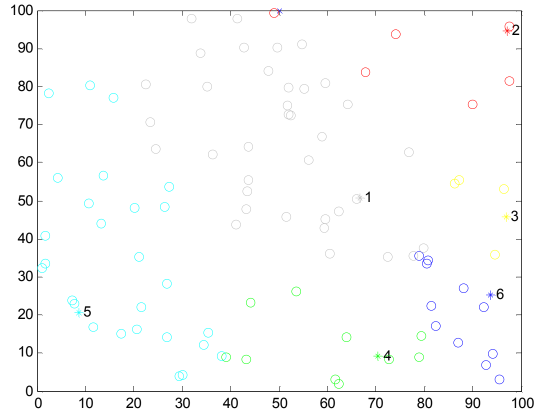

Fig. 18: B.S. (50, 175) and F.S. (50,100) with non-confirmed message, clusters are formed.

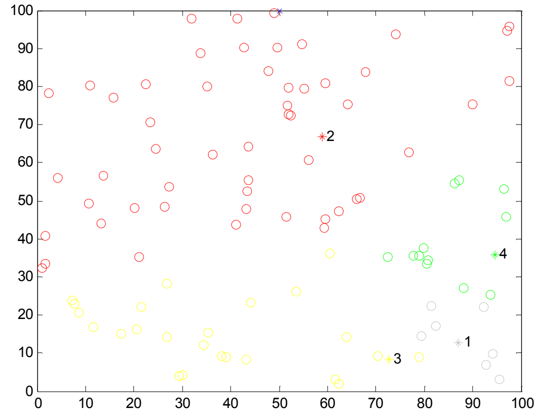

Fig. 19: B.S.(50, 175) and F.S.(50,100) integrated with the non-confirmed message in 600 rounds.

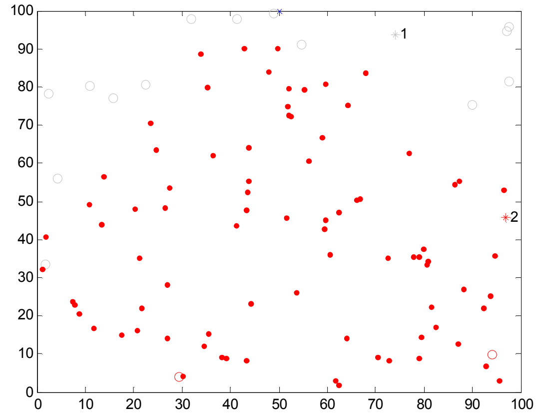

Fig. 20: B.S. (50, 175) and F.S. (50,100) integrated the non-confirmed message in1200 rounds.

Fig. 21 shows nodes' lifetime in rounds. Simulation shows that the first node ran out of its energy at round 420. Fig. 22 shows nodes' lifetime in every round. Simulation show that the first node ran out of its energy at round 680. Fig. 23 shows nodes' lifetime in rounds. Simulation shows that the first node ran out of its energy at round 750. Fig. 24 shows nodes' lifetime in every round. Simulation show that the first node ran out of its energy at round 950.

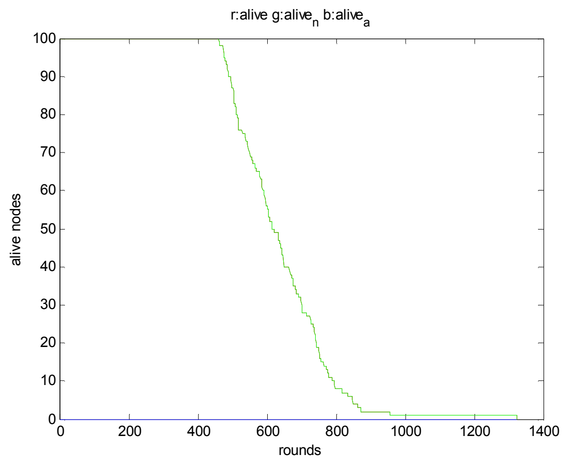

Fig. 21: Network lifetime with confirmed message and B.S. (50, 175).

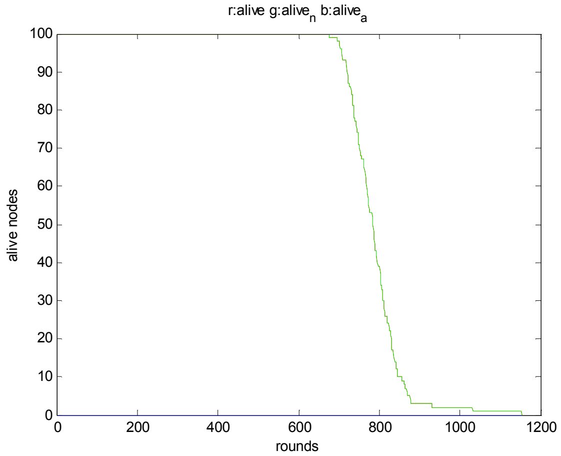

Fig. 22: Network lifetime with confirmed message and B.S. (50, 175), F.S. (50, 100).

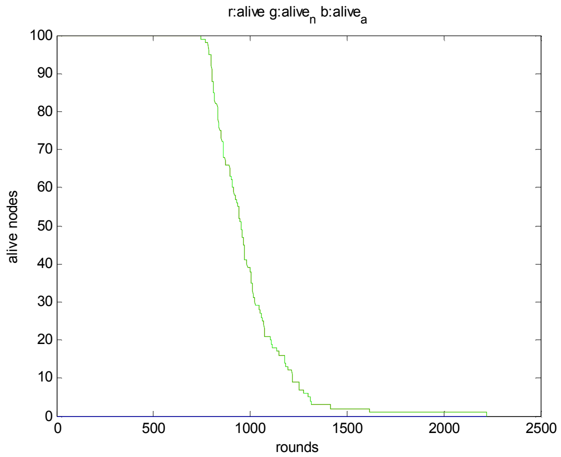

Fig. 23: Network lifetime with non-confirmed message and B.S. (50, 175).

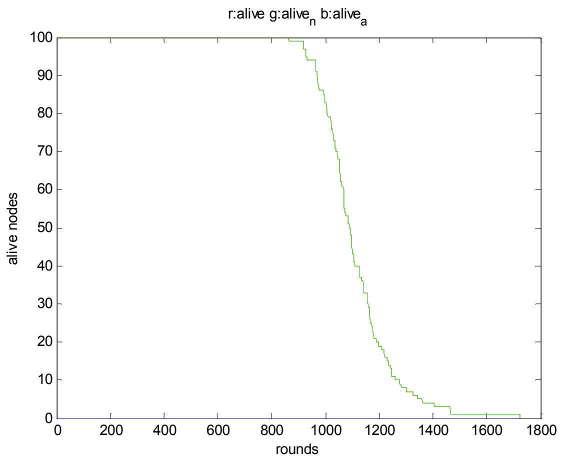

Fig. 24: Network lifetime with non-confirmed message and B.S. (50, 175) and F.S. (50, 100).

Fig. 25 shows the total energy changed in rounds with confirmed message as the base station is at the point (50,175). Fig. 26 shows that the total energy changed in rounds as the base station is at the point (50,175) and the forwarding station is the point (50,100) with confirmed message. Fig. 27 shows the total energy changed in rounds with the base station is at the point (50,175) with non-confirmed message Fig. 28 shows the total energy changed in rounds and the base station is at (50, 175) as the forwarding station is at (50,100) with the non-confirmed message .

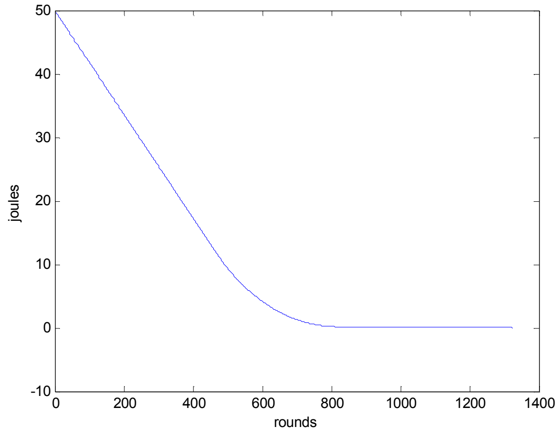

Fig. 25: Total energy changed in rounds with confirmed message, B.S. (50,175).

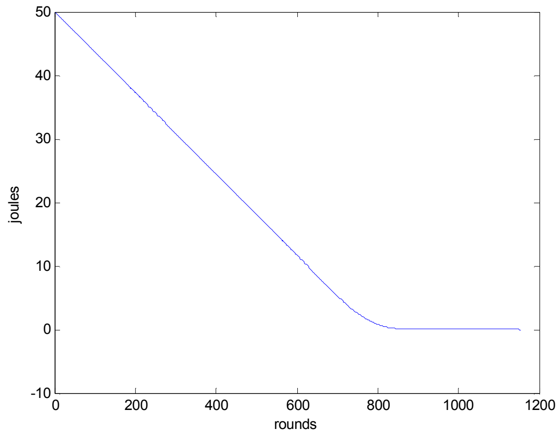

Fig. 26 Total energy changed in rounds with confirmed message, B.S.(50,175) and forwarding station F.S.(50,100).

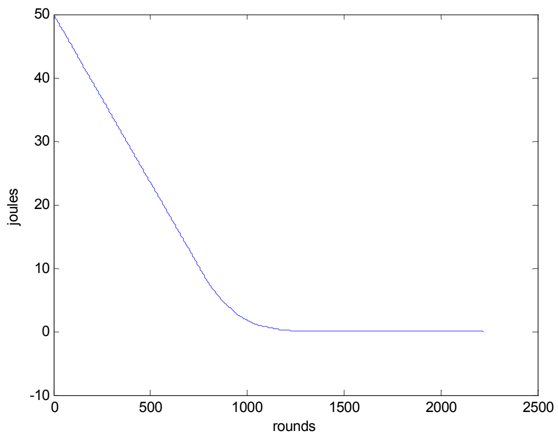

Fig. 27: Total energy changed in rounds with non-confirmed message, B.S. (50, 175).

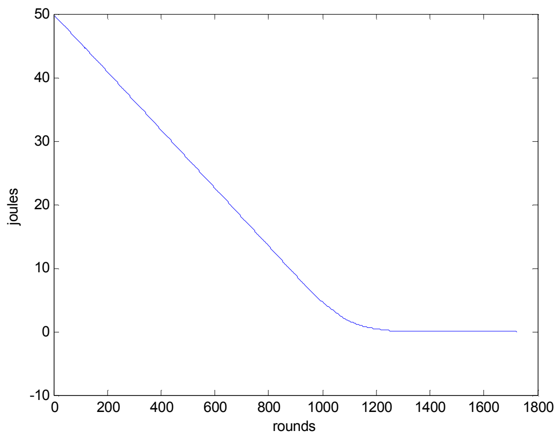

Fig. 28: Total energy changed in rounds with non-confirmed message, B.S. (50, 175) and F.S. (50, 100).

4 Conclusion

This paper proposes a forwarding station integrated non-confirmed routing protocol so that sensor nodes are no longer need to transmit directly the message back to the base station. Both a non-confirmed routing protocol and forwarding station in this paper are integrated in order to extend the entire ad-hoc wireless network lifetime longer. The simulation result reveals its performance is much better. The proposed method has the characteristic of faster response time for all messages back to the base station and also less energy used for each sensor. However, since the energy of transmitted unit used depends on the distance to decide how much the energy is used. With the forwarding station, the long distance from each cluster to the base station is removed and replaced. Therefore, the lifetime of each cluster head is extended. Finally, the battery lifetime of both the sensor node and the cluster head are extended so that the entire ad-hoc wireless sensor network lifetime is reasonable extended.

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