This document includes two parts:

1. In the first part we reply the reviewer questions and comments (we address each comment separately with detailed answers)
2. In the second part we place the newly revised version of our paper.

REVIEW 1

**Major Comment**

*Only the following concern MUST be addressed before it can be considered for publication. The authors claim that this is the first study on expanding holes. In fact, there are numerous studies on coverage-hole detection, hole boundary search and repair of coverage holes in WSNs. The survey of recently related works (with all references are before 2011) should be updated to prove the statement. The following references and their technical surveys can be added in the revised manuscript:*  
<http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=7249351>  
<http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=6554783>  
<http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=6214061>

ANSWER

We have checked the literature related to Wireless Sensor Networks with Holes (and similar concepts) with cautiousness, and also some areas remotely related to, and have not identified any work that considers the same approach that we use: we monitor the network area where a significant hole is expanding i.e. the shape of the hole and the network topology is changing all the time. Thus we claim this paper is the first to consider this dynamic hole perspective (to our best knowledge); this work can be seen as an initial attempt to try discovering into an unknown area.

We have carefully reviewed these 3 mentioned papers and found that these results still belong to the rich literature on the static hole perspective; however, we have included these in the related work section of this new version as we found these relevant and interesting.

We thank the reviewer for the useful comment and suggestion!

REVIEW 2

*Comparing to the conference paper, the current manuscript is significantly enhanced in term of presentation. Various definitions, sentences, paragraphs have been rephrased, however the major contribution of the theory part (i.e., Section 2) does not contain novelty. Therefore, a sufficient content in the evaluation part should be added in order to match a journal's requirement.  
  
Besides that, the newly proposed protocol has been not compared to other state-of-the-art ones. The extensive evaluation results are expected to present with the aim of proving the protocol's effectiveness. In the current state, the manuscript does not well support the aforementioned issues. Please check the detail comments below.*

First we greatly thank for the time and effort the reviewer has given to our work! We appreciate so much his work and great comments that would be useful for increasing the quality of our paper.

I have to confess that as the leader of our research group I had not spent enough time as I had wanted for the conference version (due to some recent health problem and keeping up with the heavy workload). That is, even our conference paper got praised by the program committee (thankfully, we got the Best Paper Award) but I realized that there were several issues/problems (though not big) in the conference version – we escaped from that because it seemed we had come up with some rather original idea (we claim that our paper is the first to consider the dynamic hole scenario).

Hence, in the journal paper I have indeed heavily revised and improved in several matters: on readability and clarity (almost rewritten some major parts), on preciseness of several definitions and algorithm description, and especially, on improving the efficiency of our algorithms. We did add new work into out algorithms: although the ideas for adding new elements are not really big but they significantly improve the HBD algorithm in term of cutting down the communication overheads and delays. This clearly asked for the renewing of our whole evaluation part; we did redo this and because of new findings, we even extend our evaluation framework significantly.

Due to the timing problem (I submitted the first journal version far too late, with long overdue) I did not manage time to mention these important differences as compared with the conference version (not explicitly required by the Chairs).

Below I will answer the detailed questions from the Reviewer that would also further clarify about these major differences.

*1. The manuscript does not cite or mention to the conference paper, which is obviously a previous work. The authors should add an explanation about the main difference between the two versions.*

ANSWER:

In this new version, I have added detailed comparison about these two versions at the end of the introduction part. For your reading convenience, let me include this mentioned text below:

*A preliminary version of this paper appears in [12]. Besides a significant revision effort for improving the clarity, formality and preciseness we also add new substantial elements to this full version. That is we reshape and adjust some important parts in our proposed algorithm and thus make it more efficient; as a result, we redo the evaluation task but in a larger scale for obtaining a more insightful about the performance of our algorithm. Below we briefly mention the most important adjustments. In section 2.1, for the task of detecting a hole boundary we justify our decision to choose the approach used in [10] over the one in [26]. In section 2.2 we optimize the way we define and use Bitmap Presentation for reducing incurred communication overhead and delay. In section 2.3 we tune the process of forwarding the hole boundary info towards the sink(s): the pivots fully involve in this process that increases the efficiency of the whole mechanism.  
  
Compared to the previous version, moreover, we also extend our evaluation work to a significant deeper level where we redesign a new, significant larger set of simulation scenarios, inspired by new observations and thus obtain new findings.  Most notably, our 3 main simulation settings (for studying the effects of 3 system parameters: Dead Node Threshold, Notification Threshold & Report Threshold) are all extended by our deployment of two different scripts of a hole expanding (we deployed just one script in the previous work), which are called Fast Expansion  and Slow Expansion. We focus more on the Fast Expansion scheme (a hole expands fast for simulating a forest fire) and we identify some value region of Dead Node Threshold that could optimize our algorithm. We also extend our study on these main parameters with some initial consideration of the relationship with another variable: the grid cell size. In spite of this rather extensive evaluation analysis there still remain many unknowns that can be challenging enough for good results in future work (we still think of this work as an initial effort of a long way to go).*

In this new version, I also added a new part (section 3.1) to provide the experiments we did for comparing the two main approaches in detecting a hole boundary (references 10 and 25 in the previous journal version): in the last journal version we did mention this comparison (in section 2.1) but omitted the simulation experiment results for it. *2. Why are the simulation settings and performance metric in two versions different? More specifically, the network size, the number of nodes, and DRE are difference. Is there any clear reason for that? Otherwise, it makes the results are neither comparable nor consistent.*

ANSWER:

As mentioned above, we have recreated the evaluation part and with a significantly changed framework for providing a more insightful view to our algorithm mechanism and its efficiency. The changes have induced after we have found some findings: e.g. in this journal version we claim the DNT=1.3x and the region around would make the best choice, minimizing both DRE (we use DRE instead of the False Positive Ratio in the conference paper which was vague and could indicate wrong thing) and AR. This finding and others affected on our decision to extend/redesign our simulation settings, and we also added a new dimension of investigating by introducing two Hole Expansion Scripts – one for fast and one for slow expansion scenario.

*3. Is there any different between the "Simulation time" in Table 1 and in other table? If yes, please add the explanation.*

ANSWER

This issue came because of a misunderstanding due to our poor word choices. While the term “Simulation time” in the former case means the total execution time (in real word) to be simulated, it should have meant a moment of time (that we captured the data) during a simulation. Now in this new version we change the later to be “Timestamp – simulation moment" in the corresponding tables for better understanding.  *4. In Fig. 5, the average values of several runs are expected to show the trend.  
5. The similar requirement as in (4) for Fig. 6, 8, 9.*

ANSWER: (for both Q4 and 5):

Perhaps the issue mentioned above about the vague term “Simulation time” being used in the figures has affected our analysis about trends. We have analyzed to make the general trend clearer in this new version. For example, we have revised the second paragraph in 3.3.1 Effect of Dead Node Threshold):

*Fig. 7 and 8 show the simulation results of our first simulation settings (with the Fast Expansion script) on the effect of DNT on the Death Report Error (DRE) and the Approximation Ratio (AR), respectively. It can be seen that the DRE tends to decrease with the increasing of the time values during the simulation. That is, for all the different DNT values, the trend is that the performance keeps improving (DRE gets closer to 0% and AR gets closer to 1) along the the simulation process (better performance for captures at later simulation moments - larger timestamps).*

We also have similar notes at other places.

*6. Figure 7 actually shows two tables of the results. Maybe the tables are enough.*ANSWER:

We have changed the format so the figure is replaced by just 2 tables.

*7. The definition of CE is unclear, CE is the energy consumed by one node or whole network?*

ANSWER:

We now have this definition below at the beginning of section 3.2 “Experiment Deployment and Settings”:

* Consumed Energy (CE) of network is computed as the average energy consumed by a node in the network.

That is, CE is ratio of the sum of all energy spent by all the nodes and the number of the nodes.

*8. The author may consider to change the captions of sub-figures in Fig. 8, Fig.9 to improve the readability.*

ANSWER:

We have fixed that.

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Again, we thank the Reviewer so much for his time, patience and very useful comments!

REVIEW 3

**Comment 1**. *The paper is well written with clear structure.  
The proposed solution is more or less based on the reference [10] and [25] however there is no clear presentation about the original work of [10] and [25] mostly the main idea of hole detection of [10]. Authors should add a small part about this.*

ANSWER:

We thank the reviewer for the thoughtful comments which raise interesting discussion.

The Hole Boundary Detection algorithm in our paper is inspired by the original work in [10]. Note that, however, our main object is to capture the behaviors (notable changes in shape) of an expanding hole while the work in [10] consider the static hole scenario only. Thus, our algorithm inherit little from [10] as we focus on many new challenging issues such as: approximation of hole shape, fully distributed mechanism and etc. Also, our major achievement could be seen in our Hole Boundary Update which is original.

For this new version, we have added two paragraphs for reviewing these two mentioned important papers at the end of the related work section. We also added a new part (section 3.1) to provide experimental results in comparing these two.

**Comment 2.** *According to the proposed Hole detection algorithm, the algorithms find different boundary segments between stuck nodes. How these boundary segments are connected together to make the complete boudary cycle? Is it possible that the algorithm finishes with un-connected boundary segments?*

As we mentioned above our Hole Boundary Detection algo inherit from [10] where the main process of creating a cycle traveling around the hole has been supported with proof by mathematic rigor. Hence, we also inherit the nature of this basic cycle process with the guarantee of producing a complete (and connected, of course) cycle, i.e. a polygon. Note that, however, our version of HBD process is to identify the unit cells (grid squares) that intersect with the hole; perhaps a more intuitive and less complicated could be created for our own HBD version.

Again we thank the reviewer for his great comments which inspire interesting discussion!