ZBP: A Zone-based Broadcasting Protocol for Wireless Sensor Networks

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***Abstract*—Wireless Sensor Networks (WSNs) have been widely used in motoring and collecting interests of environment information. Packet flooding or broadcasting is essential function for establishing a communication path from sink node to a region of sensor nodes. However, flooding operation consumes power and bandwidth resources and raises the packet collision and contention problems, which reduce the success rate of packet transmissions and consume energy. This article proposes an efficient broadcasting protocol to reduce the number of sensor nodes that forward the query request, hence improves the packet delivery rate and saves bandwidth and power consumptions. Sensor node that received the query request will dynamically transfers the coordinate system according to the zone-ID of source node and determines whether it would forward the request or not in a distributed manner. Compared with traditional flooding operation, experimental results show that the proposed zone-based broadcasting protocol decreases the bandwidth and power consumptions, reduces the packet collisions, and achieves high success rate of packet broadcasting.**

Keywords- Sensor network; protocol; zone-based; flooding; broadcasting; packet collision.

I. INTRODUCTION

Recent rapid advances in scientific and technological progress have created small size, low-power, low-cost, multi-functional miniature sensor devices with sensing, computing, and wireless communication capabilities. These sensor nodes collaborate among themselves to establish a *Wireless Sensor Network* (*WSN*), which has been widely used for various applications, including armaments defense, location tracking, widespread environmental sampling, and monitoring health, natural habitats, remote ecosystems, forest fires, disaster sites, and so on. A *WSN* is composed of a sink node and a large number of sensor nodes that are densely deployed in the particular area. The sink node is a control center which typically initiates a request demand for collecting information from a specific region and analyzes the collected information. Linked by a wireless medium, the sensor nodes perform distributed sensing tasks and transmit the sensed information to sink node or a particular region of sensor nodes respectively in user-demand and event driven manners. Recently, several protocols have been developed for *WSN*. The main concerns of related study could be classified into two categories, namely sensing and communication. A number of protocols [1] have been developed to maintain the sensing accuracy for special applications, such as location tracking and fault-tolerance. Some researches develop communication protocols [2] for providing *WSN* with multi-hop data communication services.

The communicative behaviors in *WSNs* can be characterized by two different types: routing (*node-to-sink*) and broadcasting (*sink-to-node* or *node-to-node*). Broadcasting is an essential communication requirement for sink and sensor nodes. A sink node usually floods the query request to a region of all sensor nodes in a user-demand manner, asking these nodes for returning environment information. Such an application in *WSN*s requires a broadcasting protocol to deliver the query information from sink node to all sensor nodes in the specified region.

In developing broadcasting protocol, alleviating the packet collision phenomenon will improve the packet delivery rate, which determines whether or not the sensor node will return the sensed information to sink node and thus control the accuracy for a query request. In addition, selecting proper sensor nodes to execute the broadcasting operation will not only alleviate packet collision phenomenon but also save the bandwidth and power consumptions, making contribution to both transmission delay and network lifetime. Hence, developing an efficient broadcasting protocol to avoid collision and contention problems is important for *WSN*s.

Packet flooding is the general technique for broadcasting a message over Ad Hoc networks or *WSN*s. Most protocols [5] proposed in previous research require to broadcast a message by each node. As shown in Fig. 1, the source host initiates a flooding request to the entire network. On receiving the packet, each node rebroadcasts the packet to its neighbors so that the packet could be delivered to all nodes in network.

Although flooding is simple and common used for constructing a communication path in protocols developed for MANET or *WSN*s, however, it consumes bandwidth resource

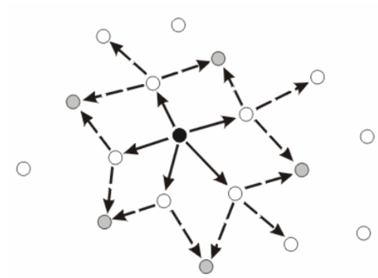

Figure 1: Flooding operation will create packet collision.

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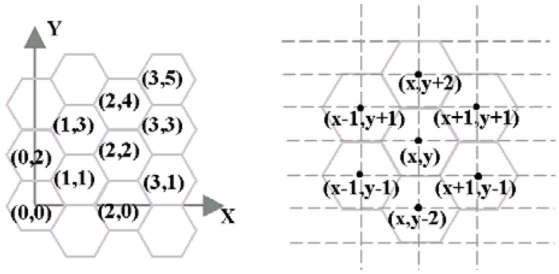
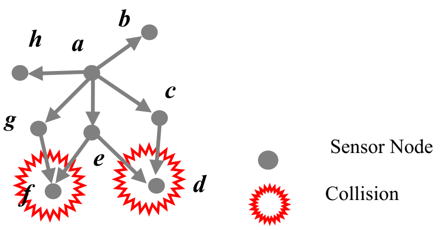


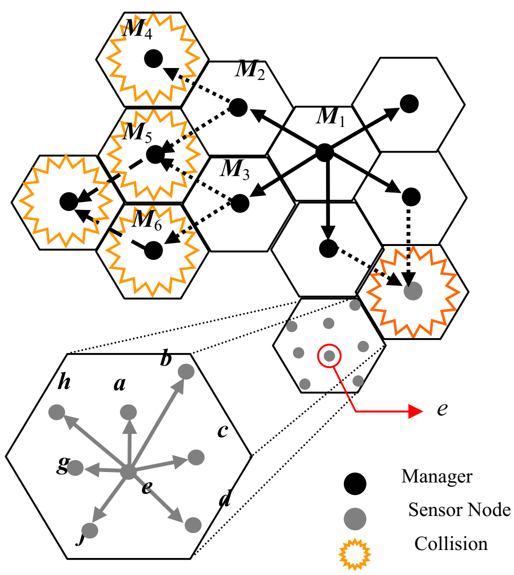
(a) Each cell has unique ID in CBM system.

(b) The relation of coordinate of neighboring cells.

Figure 2: Coordinate system of CBM[6]



(a) Collision caused by node-level flooding.



(b) Collision caused by zone-level flooding.

Figure 3: The impact of node-level and zone-level flooding.

and creates packet collision and contention problems, which reduce the success rate of packet delivery [4]. Ni and Tseng [4] pointed out the negative effect of broadcast operation and proposed various protocols to reduce the packet collision. Stojmenovic etc. [6] proposed techniques to vote some nodes as intermediate, inter-gateway, or gateway nodes to perform the packet transmission and discussed the success rate of broadcasting. To further reduce the number of flooding packets, many location aware protocols [3] partition the MANET into several grids or cells. Nodes in each partitioned cell will vote for a manager to manage the cell, with the manager being responsible for controlling message exchange with the managers of neighboring cells. Hosts wishing to establish a communication path should first send a request packet to their manager, and the manager will then relay the packet to neighboring managers in a flooding manner until the manager of the destination node is found. The extent of packet transmission is thus significantly reduced since only managers relay the request packets between cells. Although the grid-based or cellular-based management largely reduce the number of nodes executing the flooding operation, however, all managers participating flooding operations also creates the packet collision phenomenon.

To reduce the cost of broadcasting and alleviate the packet collision phenomenon, this article presents an efficient broadcasting protocol for transmitting a packet from source to a region of all sensor nodes in a *WSN*. The source could be considered as the first sensor node that receives the query request from sink node and is located in the specified region. Based on the Cellular-Based Management [7], the proposed zone-based broadcasting protocol selects a set of managers and schedules the transmitting delay for the selected managers to alleviate the packet collision phenomenon. Compared with the traditional flooding operations, experimental results show that the proposed broadcasting protocol reduces the bandwidth and power consumption, avoids the packet collisions, and achieves high success rate of packet delivery.

The rest of this study is organized as follow. Section 2 illustrates the backgrounds and basic concepts of the proposed broadcasting protocol. The efficient broadcasting protocol is proposed in Section 3. Meanwhile, Section 4 proposes the performance evaluation of the proposed broadcasting protocol. Conclusions are finally made in Section 5.

II. BACKGROUNDS AND BASIC CONCEPTS

This section first reviews the Cellular-Based Management protocol and discusses the collision problem, then presents the basic concept of the Zone-Based broadcasting protocol.

To reduce the number of nodes that transmit the request message in WSN, the Cellular-Based Management (CBM) [7] is adopted herein. The CBM geographically partitions the entire network region into several disjoint and equally sized cellular zones. Figure 2(a) illustrates the partitioned network region. Each cell is assigned a unique Cell-ID, as shown in Fig. 2(a). Figure 2(b) presents the relationship between the Cell-ID of two neighboring zones. The CBM model allows the manager to communicate directly with neighboring managers. The node can identify which cell it is located in. In each cell, the node that is geographically near the center of this zone will play the manager role for executing the information exchange. Whenever a member node desires to establish a communication path, it sends a request to the manager and the manager of each cell then takes responsibility for setting up the communication path. The extent of packet flooding is thus significantly reduced since only managers relay the packet between cells.

Although CBM protocol largely reduces the number of nodes that transmit the flooding packet, however, all managers transmitting the flooding packet also creates packet collision phenomenon. Figure 3 shows the comparisons and their impact of node-level flooding and manager-level flooding. In Fig. 3(a), sensor node *a* broadcasts a message to neighbors *b*, *c*, *e*, *g*, and *h*. On receiving the message, nodes *b*, *c*, *e*, *g*, and *h* broadcast the received message at the same time, causing packet collision at nodes *d* and *f*. Since sensor nodes *d* and *f* do not receive the request packet, they will not transmit the sensed data to sink node, resulting low accuracy of the collected information in sink node. In addition, all nodes *a*, *b*, *c*, *d*, *e*, *f*, *g* and *h* execute the packet broadcasting, causing power and bandwidth consumption. On the contrary, consider Fig. 3(b). Only managers of zones participate the packet flooding. Assume manager M_1 is the source node of request message. On receiving the broadcasting message, all neighboring manages, including M_2 and M_3 will broadcast the message, resulting the packet collision occurred at managers M_4, M_5 and M_6. In the zone-based management, only managers execute the flooding operations. A large amount of flooding packets has been saved, implying the bandwidth and power consumptions have been improved. However, as the collision occurred in a zone, all sensor nodes in the zone will not receive the request packet. This will raise the problem that all sensor nodes in the zone will not transmit the sensed environment information to the manger, causing that the environment information collected by sink node is inaccuracy. How to apply the zone-based management to alleviate the packet flooding phenomenon and prevent the manager-level collision will be the main target of this article.

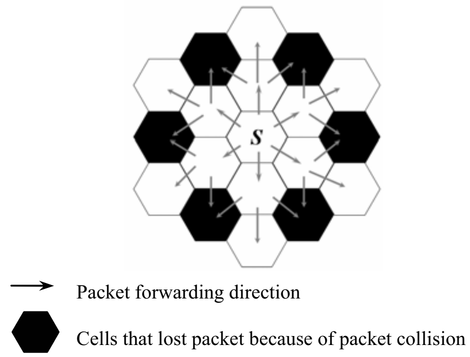


Figure 4: In CBM, managers flood the packet will create *type-1* packet collision.

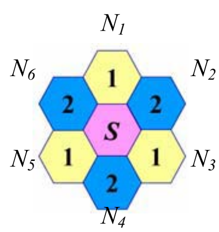


Figure 5: Delay scheduling for neighboring cell of *S* to avoid collision.

To illustrate the basic idea of this article, an example is shown below. Consider Fig. 4. Let *S* denote the cell-ID of source sensor node. Once the managers of neighboring cells of *S* receive a query request message, the black cells in Fig. 4 will have a packet collision. A scheduled delay for broadcasting can avoid the packet collision (named *type-1* collision). Consider Fig. 5. Each neighboring cell of cell *S* is labeled with a number, denoting the transmission time of request packet. Let N_i denote the cell-ID of the *i*th neighboring cell of *S* in clockwise order. As shown in Fig. 5, manager *S* broadcasts the query request to its neighboring managers at time unit 0. On receiving the query message, managers of cells N_1, N_3, and N_5 will broadcast the message to its neighboring managers at time unit 1, but managers N_2, N_4, and N_6 will delay one time unit, then broadcast the message at time unit 2. Thus, the collision at cells N_1 and N_2 can be avoided. Once the managers of N_2, N_4, and N_6 received the query message, it checks the cell-ID of source and its cell-ID. Applying the new coordinate system as described in Section 3, each neighboring manager N_i of cell *S* will execute the following formula to derive how many time units it should delay:

Delay (*i*-1) mode 2 time unit

To further reduce the number of managers that transmit the flooding packet, the network region is partitioned into six sub-regions according to the six direction of source cell *S*. As shown in Fig. 6, six lines X_1, …, X_6 partition the region of zone-based sensor network into six sub-regions A_1, …, A_6. For example, sub-region A_1 consists of cells located in the first sub-region and marked by gray color whereas sub-region A_2 consists of cells located in the second sub-region and marked by white color. Each sub-region could be partitioned into many bands in a width of three. Taken sub-region A_1 as an example, along direction X_2, sub-region A_1 can be partitioned into several bands by sub-axises S_1, S_2, …, and so on, as show in Fig. 7. The width of each band is three cells. Managers of cells that are located on the sub-axises are responsible to forward the query request message, resulting that the broadcasted message could be transmitted to all managers of its band, as shown in Fig. 8. Therefore, the broadcast message initiated by source manager *S* could be received by all managers..

If there is no delay scheduling on those managers that participate the flooding operations, packet collision will occur. The packet collision will raise the problem that some manager cannot receive the request message, resulting the collected environment information in sink node is inaccuracy. Figure 9(a) demonstrates the sequence of packet flooding in sub-region A_2. Numbers labeled on some cells denote the time slot that the manager of that cell transmits the request message. As shown in Fig. 9(a), collision is occurred in the cell marked by black color. The packet collision is occurred because that managers of main-axis and sub-axis transmit packet in the same time. This type of collision is called *type-2* collision. The *type-2* packet collision could be avoided if manager of first cell located on the sub-axis delays the packet transmission for a time unit.

In the next section, a coordinate system will be derived. Each manager can automatically derive the delay schedule in a distributed manner according to the source manager's cell-ID.

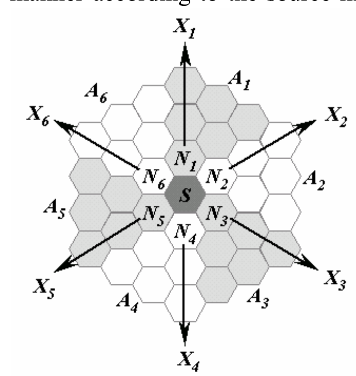


Figure 6: Neighboring cellulars of source cellular *S* are denoted by N_i. Six axis X_i partition the WSN region into regions A_i.

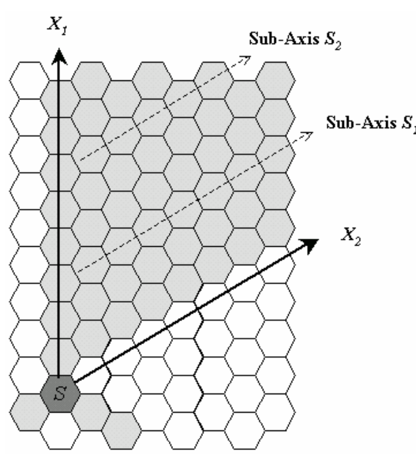


Figure 7: Sub-Axis S_i partitions each sub-region *Ai* into bands with width three.

Appling the proposed broadcasting protocol, packet could be flooded over the Zone-based sensor network without any collision.

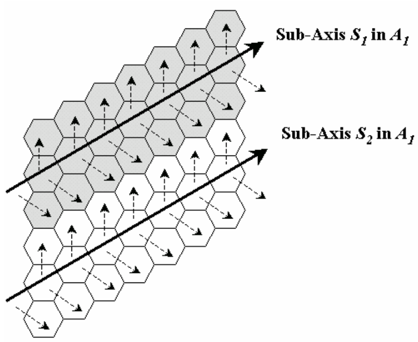


Figure 8: In sub-region A_i, manager of cell location on Sub-Axis S_i executes the packet broadcasting. All managers in this sub-region will receive packet without collision

III. THE BROADCASTING PROTOCOL

This section firstly defines a source oriented coordinate system. Based on the coordinate system, the broadcasting protocol is proposed. The derivation of source-oriented coordinate system depends on the location of source node. That is, cell-ID of each cell is derived from the location of source node. Manager of each cell will check whether or not it should transmit the packet according to its cell-ID in the source-oriented coordinate system. Executing the proposed broadcasting protocol, packet can be transmitted to all sensor nodes without collision. The following defines some notations that will be used to describe the coordinate system and broadcasting protocol.

Definition ***Manager M_k***

Cell-ID K or simply *cell K* denotes the cell whose ID is *K* in short. Manager M_k denotes the manager of cell *K*. ■

Definition **Neighboring cells N_k**

As shown in Fig. 6, the sensor network is partitioned into six disjoint sub-regions. Each neighboring cell of source cell belongs to different sub-region. The neighboring cells of source cell are clockwise numbered by N_1, N_2, N_3, N_4, N_5, and N_6. ■

Definition **Main Axis X_k**

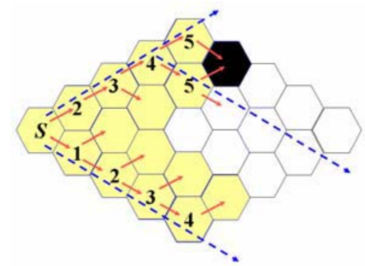
As shown in Fig. 6, each cell has six neighboring cells. Extending from the cell *S* to its six neighboring cells, there are six axis X_1, X_2, X_3, X_4, X_5, and X_6. Managers of the cells that are located on the axis X_1, X_2, X_3, X_4, X_5, and X_6 will be responsible to transmit the broadcasting packet so that all managers may receive the packet. ■

Definition **Area A_k**

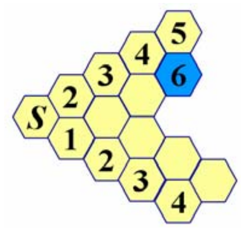
The six axis X_1, X_2, X_3, X_4, X_5, and X_6 will partition the WSN region into six sub-regions A_1, A_2, A_3, A_4, A_5, and A_6. Note that the cells located on axis X_i belong to region A_i. ■

Definition **Sub-Axis S_k**:

As shown in Fig. 7, several lines parallel to Main Axis X_i partition the region A_i into several bands. Each parallel line is defined by *Sub-Axis* S_k, $k \geq 1$. The Sub-Axis S_i and S_{i+1} have a distance of 3 cells. Manager of cells located on Sub-Axis will execute the packet broadcasting for a request message. This will guarantee that all managers in WSN will receive the packet without collision. ■



(a) *Type-2* collision occurred at the first cell of sub-axis.



(b) Delay scheduling to avoid the type 2 collision.

.Figure 9: *Type-2* collision and it's the delay scheduling

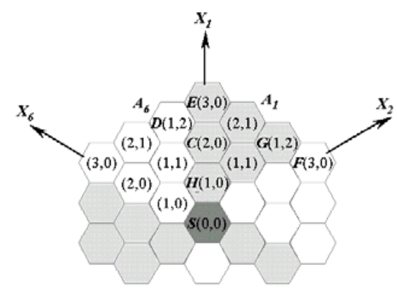


Figure 10: The x-axis and y-axis of region A_i are X_i and $X_{(i+1)\ mod\ 6}$, respectively.

Treating *Source Cell S* as the origin of the coordinate system, the main Axis X_i partitions the WSN region into six sub-regions A_i, $1 \leq i \leq 6$. To efficiently check whether or not the manager should execute the packet broadcasting, a coordinate transformation system is developed for each partitioned sub-region A_i. Each manager can independently determine whether or not it should execute the message broadcasting, according to the received packet. Fig. 10 is an example of new coordinate system for sub-region A_1. In sub-region A_1, main axis X_1 and X_2 are considered as the *x*-axis and *y*-axis of the new coordinate system. According to the *x*-axis and *y*-axis, coordinate of each cell in sub-region A_1 can be derived, as shown in Fig. 11(a). Assume that main axis X_i belongs to sub-region A_i and main axis X_{i+1} belongs to sub-region A_{i+1}. In general, in sub-region A_i, main axis X_i and X_{i+1} are considered as the *x*-axis and *y*-axis of the new coordinate system. According to the *x*-axis and *y*-axis, coordinate of each cell in sub-region A_i can be derived, as shown in Figs. 11(a)-(f). As far as a manager knows which sub-region it locates, it can derive the new coordinate of the cell it locates by applying the rules listed in Fig. 12. According to the derived new coordinate, manager can easily check whether or not it is located on the main axis X_i or sub-axis S_i, and determines that whether or not it should perform the message transmission. In the following, we introduce how the manager knows the sub-region A_i it locates.

In CBM [7], each manager records the ID of neighboring managers. In the proposed broadcasting protocol, packet sent by manager *M* contains the old coordinate, the new coordinate

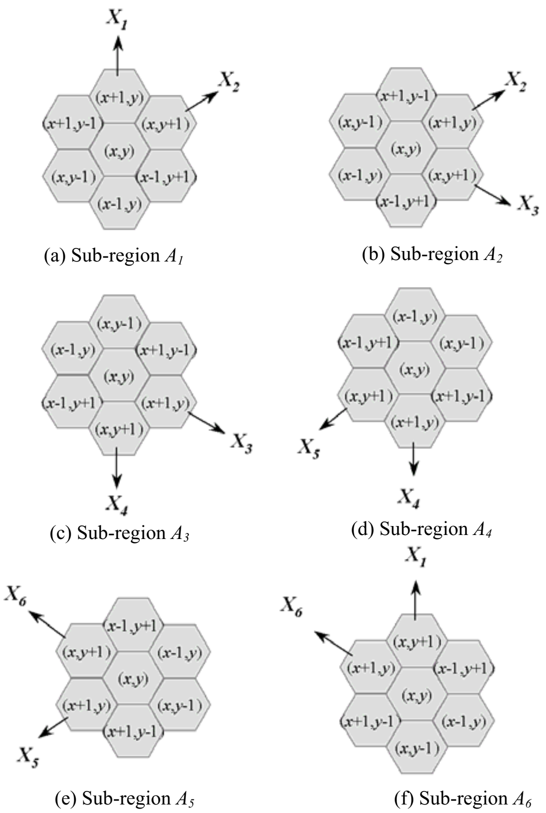


Figure 11: Source-oriented coordinate system.

of cell and the sub-region A_i that M located. As the neighboring manager of M receives the packet, it can easily derive the sub-region and then apply rules in Fig. 11 to evaluate the new coordinate of cell it located. For example, consider Fig. 10. Assume source manager M_s sends a packet to its neighbors. As manager M_H receives the packet, it checks the old coordinate of M_s and knows that it locates at the neighboring cell N_1 of source cell S. This implies that manager M_H is located in sub-region A_1. Applying rule of Fig. 11(a), manager M_H derives the new coordinate of the cell it located is (1, 0). After that, M_H will broadcast the packet that contains sub-region A_1, old coordinate, and new coordinate (1, 0). Neighboring managers of M_H thus can derive their new coordinate. Similarly, manager M_E will receive the packet sent by M_C. and then apply the rule shown in Fig. 11(a) to derive the new coordinate of cell it located. To illustrate the new coordinate evaluation of a manager that receives a packet from other sub-region, another example is given in the following. Consider Fig. 10. When managers M_D receives the packet sent from M_C, it checks the original coordinate of the received packet and knows that it belongs to sub-region A_1. Applying the coordinate rule shown in Fig. 10(b), it obtains a new coordinate (3, -1). Because that manager M_D does not belong to the sub-region A_1 that packet sent from, it further applies the coordination transformation rules shown in Fig. 12. Thus, manager M_D obtains a new coordinate (1, 2) of the cell it locates. Similarly, on receiving a packet sent from M_G, manager M_F will execute the same operation. After applying the coordination transformation rules shown in Fig. 12, manager M_F obtains the new coordinate value (3, 0) of the cell it locates.

The header of broadcasting message contains Source Node ID, Broadcasting ID, Broadcasting Sequence, Sub-region, the original coordinate (x, y), and message. The broadcasting Sequence Number is used for identify whether or not the received packet has been sent by the current manager. As a manager receives a broadcast packet, it extracts the information

Coordination Transformation Rules:

/*Manager receives the broadcasting packet (Source Node ID, Broadcasting ID, Broadcasting Sequence, Sub-region, *x*, *y*, message) */

```
Rule 1：
If my_y <= 0
    my_y = my_x
    my_x=1
Rule 2：
If my_x = 0
    Swap(my_x, my_y)
```

Figure 12: Coordinate Transformation Rules.

such as sub-region and the original coordinate (x, y) to evaluate the new coordinate. According to the received sub-region, manager assumes that it is located in the same sub-region and use the corresponding new coordinate system listed in Fig. 11. To avoid the sender and receiver belong to different sub-regions, as the new coordinate obtained, the manager will check the coordinate transformation rules and determine that whether or not the coordinate should be transformed. As the new coordinate obtained, the manager knows whether or not it should participate the packet broadcasting.

The proposed ZBP is divided into three phases. In the first phase, manager that receives the broadcasting packet will derive the new coordinate. Then, in the second phase, the manager will use the new coordinate to determine whether or not it should broadcast the message. Finally, in the third phase, manager will evaluate the timing for sending the broadcast packet so that collision could be avoided. The operation of the first phase has been illustrated previously. In the second phase, manager that satisfies one of the following criteria will execute the broadcasting operation.

(1) Manager located on the main axis $\boldsymbol{X_I}$: a manager will execute the broadcasting operation if the new coordinate (*my_x*, *my_y*) of the manager's cell satisfies *my_y*=0. This indicates that the manager is lying on the main axis $\boldsymbol{X_i}$.

(2) Manager located on the sub-axis: a manager will execute the broadcast operation if the value *my_x* is a multiple of 3. This indicates that the manager is lying on the sub-axis $\boldsymbol{S_i}$.

Within one sub-region A_i, packets sent by the scheduled managers can be successful transmitted to neighbors without collision. However, some neighboring managers belong to different sub-region will create collision if they broadcast packet simultaneously. As shown in Fig. 13, managers $\boldsymbol{M_K}$, $\boldsymbol{M_L}$, $\boldsymbol{M_M}$, $\boldsymbol{M_O}$, $\boldsymbol{M_P}$ and $\boldsymbol{M_Q}$ may not receive the packet due to managers $\boldsymbol{M_A}$, $\boldsymbol{M_B}$, $\boldsymbol{M_C}$, $\boldsymbol{M_D}$, $\boldsymbol{M_E}$, and $\boldsymbol{M_F}$ broadcast packet simultaneously. Thus, applying the phase 3 of the proposed broadcasting protocol, as soon as managers $\boldsymbol{M_B}$, $\boldsymbol{M_D}$, and $\boldsymbol{M_F}$ receive the packet, they should keep the packet and delay for one time slot and then send packet to neighbors. Besides, manager $\boldsymbol{M_H}$ may not receive the packet due to that managers $\boldsymbol{M_J}$ and $\boldsymbol{M_G}$ broadcast packet simultaneously. This situation will be found in cells closed to the intersection of main axis and sub-axis. Therefore, in phase 3 of the broadcasting protocol, manager of the first cell of sub-axis is scheduled to delay a time unit. Applying the phase 3 of the proposed broadcasting protocol, as shown in Fig. 13, as soon as managers $\boldsymbol{M_J}$ and $\boldsymbol{M_G}$ receive the broadcast packet, manager $\boldsymbol{M_J}$ will broadcast the packet immediately, but manager $\boldsymbol{M_G}$ delay one time unit to avoid the collision with manager $\boldsymbol{M_J}$. The broadcast packet thus will be successfully transmitted to all sensor nodes without collision.

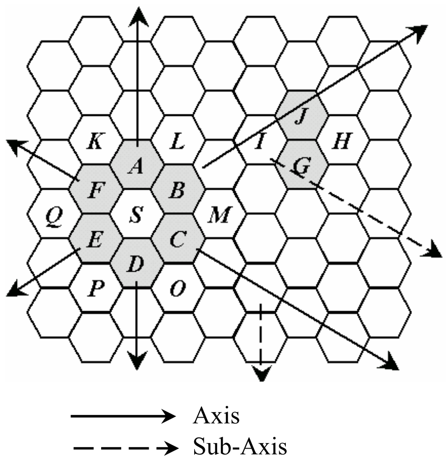


Figure 13: Transmission delay of manager M_A、M_B、M_C、M_D、M_E and M_F scheduled to avoid collision.

IV. SIMULATION

The previous section proposed zone-based broadcasting protocol (ZBP) for broadcasting a message from sink node to all sensor nodes in wireless sensor networks. By applying the proposed protocol, a subset of managers are selected in a distributed manner to execute the packet broadcasting so that the collision could be avoided. This section proposes the performance investigation of ZBP, in terms of broadcasting overhead and count for packet collision.

The number of randomly generated sensor nodes varies ranging from 1500 to 4500. Figure 14 plots the broadcasting overhead which is measured by the number of nodes that broadcast the message. Note that the broadcasting overhead also represents the bandwidth and power consumptions of sensor networks. The overhead increases with the number of sensor nodes if the uncontrolled flooding is applied. By applying the proposed ZBP, the broadcasting overhead is significantly reduced.

Figure 15 displays the effect of packet collision on the number of sensor nodes. As the number of sensor nodes larger than 1000, the packet collision is a constant since the number of managers is a constant in a fix-sized region. The proposed ZBP reduces the number of packet collision and thus saves the overhead of packet retransmission or increases the accuracy of information collected by sink node.

V. CONCLUSION

Broadcasting is an essential function required in wireless sensor networks. However, all sensor nodes broadcast the broadcasting message will raise the collision and power consumption problems which will respectively reduce the accuracy of information of sink node and reduce the network lifetime. CBM management model reduces the number of nodes executing broadcasting operation. This paper applies CBM management model on Wireless Sensor Networks to reduce the flooding phenomenon from node-level flooding to manager-level flooding. However, a collision occurred in a zone while executing manager-level flooding will raise another serious problem that all sensor nodes of the zone can not receive the broadcast message, deteriorating the information accuracy of sink node. This paper proposes an efficient broadcasting protocol that reduces the number of managers executing the broadcasting operation so that broadcasting packet can be successfully transmitted to all sensor nodes in Wireless Sensor Networks. A new coordinate system is introduced so that each manager can derive the new coordinate of its zone and determine whether or not and when it should broadcast the received message to neighboring managers. Simulation results show that the proposed broadcasting protocol reduces the collision phenomenon and overhead including power and bandwidth consumptions, hence improves the performance of Wireless Sensor Networks.

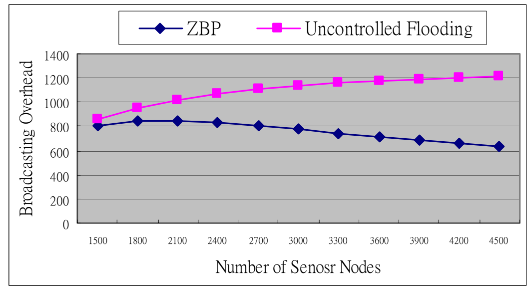


Figure 14: The success rate of packet transmission.

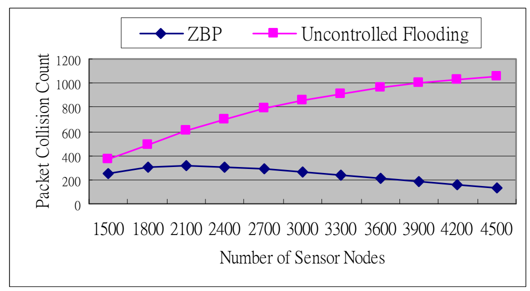


Figure 15: The number of piconets in varying the number of devices.

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REFERENCES

[1] C.-F. Huang and Y.-C. Tseng, "The Coverage Problem in a Wireless Sensor Network", *ACM Int'l Workshop on Wireless Sensor Networks and Applications (WSNA)*, 2003.

[2] Kemei Du; Jie Wu; Zhou, D., "Chain-based protocols for data broadcasting and gathering in the sensor networks", *Parallel and Distributed Processing Symposium*, 2003

[3] Wen-Hwa Liao, Yu-Chee Tseng, and Jang-Ping Sheu, "GRID : A Fully Location-Aware Routing Protocol for Mobile Ad Hoc Networks," *The 6th Mobile Computing Workshop*, pp. 1-8, March 2000.

[4] C. Y. Ni, Y. C. Tseng, Y. S. Chen, and J. P. Sheu, "The Broadcast Storm Problem in a Mobile Ad Hoc Network," *Proceedings of the MobiCom'99*, pp. 151-162..

[5] Stefano Basagni, Danilo Bruschi, and Imrich Chlamtac, "A Mobility-Transparent Deterministic Broadcast Mechanism for Ad Hoc Networks," *IEEE/ACM transactions on networking*, vol. 7, no. 6, December 1999.

[6] Ivan Stojmenovic, Mahtab Seddigh and Jovisa Zunic, "Internal Nodes Based Broadcasting in Wireless Networks," *Proceedings of the 34th Hawaii International Conference on System Sciences*, 2001.

[7] C. Y. Chang, C. T. Chang and T. T. Hsieh, "Hierarchical Cellular-Based Management for Mobile Nodes in Wireless Ad Hoc Networks," in *The IEEE 15th International Conference on Information Networking* (ICOIN-15), Beppu, Japan, Aug., 2000.