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An Energy Efficient Scheme for Detecting Redundant Readings in Cluster-based Model of Integrated RFID and Wireless Sensor Networks

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Abstract

For efficient detection of redundant readings by the overlapped reading ranges, by avoiding the unnecessary transmission of reading data and unsuccessful detection attempts, detecting the redundant readings as early as possible is critical for energy efficiency in the integrated RFID and WSNs. In this paper, we propose a cluster-based efficient detection scheme called ASER (Aggregation-based Scheme for Eliminating Redundancy) for detecting redundant readings with the purpose of attaining energy efficiency in integrated RFID and WSNs. ASER is based on a 2-Phase Aggregation (2PA) scheme whose main purpose is to localize the detection attempts without traversing nodes in the network. ASER can minimize the unnecessary overhead by detecting redundant readings in advance before they traverse along the routing path. According to results of performance evaluation, ASER shows considerable improvement in reduction of both communication cost and computational detection overhead to detect the redundancy

Keywords: RFID, WSN, Redundant Reading, Energy Efficiency, Cluster, Data Filtering

INTRODUCTION

The wireless and mobile paradigm in computing and communication has rapidly emerged in many our daily life environments. In accordance with this trend, the integration of RFID and wireless sensor networks (WSNs) gets to play very fundamental roles in the near future. RFID technology enables large volumes of data to be captured for monitoring, identifying, and locating objects at high speed. This makes RFID technology suitable for a variety applications such as supply chain management, manufacturing and distribution logistics, healthcare, security, agricultural applications and so on [1]. WSNs are networks of sensor nodes equipped with wireless interface through which they can communicate with each other in order to cooperate for gathering sensed information [2]. WSNs can be introduced in many applications such as environment monitoring, health observation, security and other commercial applications [3].

RFID systems usually consist of tags, readers, and host computers. The reader reads tag data attached to objects through communication with tags using RF signals. The host computer stores and manages the data read and transmitted by the reader. It also submits queries to readers for data needed to run applications. To manage RFID data stream, which has nature of seamless and dynamic massiveness, has posed several challenges for RFID systems to get more widespread use in diverse applications [4], [5]. Sensor nodes in WSNs are typically characterized by low power, small memory capacity, and low communication range. WSNs, however, easily achieve a large scale and dense deployment so that they can extend the coverage of area and improve the fault tolerance or robustness. Therefore, conditions or circumstances of objects can be effectively captured by sensor nodes in decentralized and large scale environments.

While RFID is suitable for identifying and monitoring objects with relative low cost, WSN are usually suitable for gathering detailed information about object conditions with networked sensors. This complementary aspects makes RFID systems to operate in a multi-hop fashion together with detailed conditions of objects especially in large scale and distributed environments. This implies that integration of RFID and WSNs (RFID/WSNs) can be useful for various applications [6], [7], [8], [9]. In particular, integration helps to implement smart environments such as Internet of Things [10] where physical objects are seamlessly identified, producing useful information over the Internet for applications [11], [12]. However, to promote RFID/WSNs, there exist several challenges including energy consumption, data cleaning, time delay and so on [13], [14], [15].

Since wireless devices have very limited battery life, low energy consumption has been one of crucial problems in RFID/WSNs. As the number of sensors increases, the time delay also increases. Hence, by efficient use of network bandwidth, satisfying time constraints is of importance especially in real time applications. The need for data cleaning stems from the inherent unreliability of RFID readers and overlapped reading areas among them which makes it very likely to produce redundant readings. Redundant readings need to be filtered out for the correct monitoring and tracking of tagged objects. Actually, the goal of data cleaning is to maintain integrity of RFID data streams in order to delivery clean data to applications. Many related works on data cleaning can be founded in the literatures [16], [17], [18], [19], [20], [21].

The redundant readings in RFID/WSNs are more likely to occur since sensor nodes are densely deployed and consequently have more overlapped reading areas with surrounding sensor nodes. The redundant readings are unavoidable as long as overlapped areas exist. As a result, to detect redundant readings as soon as possible without unnecessary transmissions of them and meaningless attempts to detect them at each node is a very critical point for successful integration. Many works for filtering redundant readings in relation to the RFID or/and WSNs appear in the literatures [22], [23], [24], [25], [15], [26], [27]. Most of them, however, address filtering problems at a reader level or a host node level. That is, energy efficient filtering by reducing transmissions of redundant readings by sensor nodes may be not of their major concerns for RFID/WSNs.

The key point to detect redundant readings in RFID/WSNs is to acquire the complete knowledge of such readings among surrounding nodes. One easy way to acquire the knowledge for redundant readings is to transmit of redundant data to the sink node along the routing path. Such transmission of redundant readings in energy-constrained RFID/WSNs incurs very undesirable effects because it consumes the unnecessary power and network bandwidth. Therefore, energy efficient schemes need to be developed to prolong network life.

Many works address the problem of energy efficient scheme for reducing transmission of redundant data in RFID/WSNs integration. In-network aggregation techniques are proposed to deal with distributed processing of data generated by different sensors [28], [29]. Though they contribute to the reduction in communication among sensors, eventually leading to reduction in the energy consumed from the batteries, they have specific purposes for only data gathering queries and also suffer from the computation overhead for data processing. Several algorithms for dealing with redundant readers also proposed to detect and eliminate redundant readers from the network for the purpose of posing a minimal communication overhead [30], [31], [32]. However, this problem is basically an NP-hard so that most of them take heuristic approaches to obtain the optimal solutions.

A series of interesting works related in-network RFID data filtering to deal with the redundant readings by multiple readers have also proposed to prolong the life of the energy-constrained WSNs [33], [34], [35]. In [34], they propose an INPFM (In-Network Phased Filtering Mechanism) to filter the global redundant readings. In INPFM, data transmission follows the routing path on WSNs, trying to filter redundant data at nodes on the path. Since INPFM is subject to a multi-hop routing, it needs to check the redundancy at every node along the routing path until the redundancy is detected. This is undesirable because it incurs much computational overhead and transmission overhead which are accompanied by high power consumption. In densely deployed WSNs, it is evident that it aggravates WSNs system. CLIF (Cluster-based In-network Filtering scheme) in [35] introduces clustering of nodes in which one node is designated as a cluster head node (CH) to whom other nodes involved in the same cluster send the data. Therefore, CHs will perform the filtering and then forward data along the routing path towards the host (base/sink) node connected to the host computer. In the case of intra-cluster redundancy which results from the nodes in the same cluster, CLIF can reduce the computation overhead and consequent transmission overhead, compared to INPFM by sending data to the head node. On the contrary, in the case of inter-cluster redundancy which results from the nodes with overlapped area even in the different clusters, CLIF also imposes computation overhead and consequent transmission overhead, since CHs follows the similar scenario to that of INPFM. EIFS (Energy Efficient In-Network RFID Data Filtering Scheme) in [33] improves CLIF by using a feedback message. If an intermediate CH on the routing path detects the inter-cluster redundancy, it sends a feedback message to surrounding CHs whose member nodes generated the redundant data. Thereafter, those CHs transmit the inter-cluster redundant data to the near CH by changing the routing paths of them. This allows EIFS to avoid unnecessary comparisons and redundant transmissions from a source CH to the detecting intermediate CH. They prove EIFS is a more energy efficient scheme than other ones such as INPFM and CLIF through simulations.

To avoid frequent feedback messages, EIFS sets a condition for sending feedback messages, which depends on the network size, number of cluster, or distance of a node. Apart from the cost of sending feedback messages, even if EIFS gains the energy-efficiency as compared to preceding schemes, it also suffers from some shortcomings. First the inter-cluster redundant data are transmitted to the intermediate CHs along the routing paths until the source CH which is involved in sending the redundant data receives the feedback message to change the routing path towards their surrounding CHs. Second, until the inter-cluster redundancy is detected, each intermediate CH on the routing path also tries to check the inter-cluster redundancy as in preceding works. Third, since nodes involved in the same cluster can have overlapped reading areas with nodes in distinct clusters, the feedback message is not immediately effective for some inter-redundant readings. Fourth, in case one particular source CH among the surrounding CHs happens to take over the responsibility of checking all inter-cluster redundancy generated by its surrounding CHs, the CH relatively consumes significant energy.

It is obvious that the undesirable overhead for detecting and transmitting redundant readings can be considerably reduced if redundancy can be detected in advance before CH of a node starts to transmit redundant reading data to the intermediate CHs along the routing path. We think the best way is to detect redundancy at a node's CH without traversing nodes along the routing path. To make this possible, the CH should have the complete knowledge of redundant readings by all surrounding nodes of nodes that belong to its cluster. For the acquisition of such knowledge, CHs of surrounding nodes should send their own redundant readings to the one CH among them. Therefore, the first important thing is to figure out a group of those associated CHs, which we call cluster head aggregation. However, to build a complete aggregation is not trivial because a surrounding node of a node can be also a surrounding node of another node which belongs to different CH from its CH. This implies that it needs to consider the transitive surrounding relationships of nodes as well as direct surrounding relationships, in order to achieve efficiency owing to early detection as much as possible. Otherwise, it is likely to miss detection of some redundancies in advance because of partial aggregation of the cluster heads. Our previous work in [36] addresses to solve this problem and proposes 2-Phase Aggregation (2PA) scheme in order to build the effective aggregation.

In this paper, to solve the shortcomings of previous works, we propose an energy efficiency scheme called ASER (Aggregation-based Scheme for Eliminating Redundancy) for detecting redundant readings in RFID/WSNs. ASER also introduces clustering of sensor nodes, and is based on the notion of cluster head aggregation scheme called 2PA appears in our previous work. Owing to the notion of aggregation, with ASER the unnecessary transmission of redundant data and useless detection attempts can be reduced, contributing to the improvement of energy efficiency after all. Then, we evaluate the performance of ASER through simulation approach.

The remainder of this paper is as follows. Section 2 briefly introduces preliminaries needed for presenting ASER, including problem overview. In Section 3, we describe our previous work called 2PA scheme to produce the aggregation. ASER is proposed in Section 4. Section 5 shows the simulation results for performance evaluation. The conclusions and future works appear in Section 6.

PRELIMINARIES

Cluster-based System Model of RFID/WSNs

In accordance with the intended purposes, there may be different approaches to integration of RFID and WSNs [37, 38, 39]. Without losing generality, we can consider a simple model of RFID/WSNs in which each wireless sensor node is integrated with one RFID reader and there is one base sensor node connected directly to the server running applications. Figure 1 shows our simplified model. A sensor node delivers RFID data by the reader and sensing data by the sensor to the server for applications via WSNs in a multi-hop fashion along the routing path to the destination.

In our WSNs, we do not pose any limitation on the deployment of sensor nodes. Sensor nodes may be positioned dynamically and arbitrarily according to the situation. That is, their positions may be static or dynamic, dense or sparse to meet the application purposes. A group of sensor nodes forms one cluster with unique identification number and one sensor node belongs to one cluster. Though we can consider the clustering criteria such as the number of nodes in the cluster and cluster's coverage distance, in this paper we do not address how to cluster nodes. One sensor node in each cluster is designated as a cluster head node (CH). Of course, CH may be changed for balancing the energy consumption. Each member nodes can communicate with its own CH directly so that it transmit tag data to its CH. Tags in the reading region of a node are read multiple times, and tags in the overlapped region by multiple nodes are also read multiple times. A CH performs data filtering in order to eliminate the redundant data, and then forwards data to other CHs on the routing path towards the base node in a multi-hop communication via WSNs.

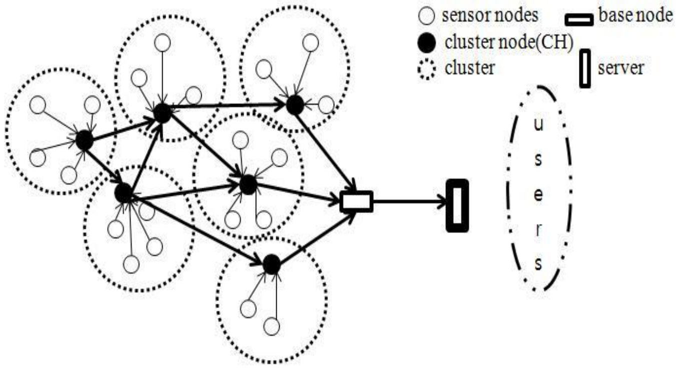


Figure 1: Cluster-based System Model

Problem Overview

A node reads data like the identity label of tags in its vicinity. We represent tag data as 3 fields: *d(Tid, Nid, Ts)*. *Tid* refers to the unique tag identifier like EPC (Electronic Product Data) standard. *Nid* refers the unique identifier of a node that read the tag of *Tid*. *Ts* is the timestamp that the node of *Nid* read tag of *Tid*. Due to the possible latency, we need to include timestamp to denote tag data. Otherwise, the incorrect filtering may deliver inappropriate data to applications, especially to query-based or event-based applications. We need to define redundant data clearly at reader level in our work.

***Definition 1* (*Redundant data*)**: For two arbitrary tag data $d_i(Tid_i, Nid_i, Ts_i)$ and $d_j(Tid_j, Nid_j, Ts_j)$, if the following conditions satisfy at the same time, $d_i(Tid_i, Nid_i, Ts_i)$ and $d_j(Tid_j, Nid_j, Ts_j)$ are defined to be redundant data.

a) $Tid_i, = Tid_j,$

b) $Nid_i, \neq Nid_j,$

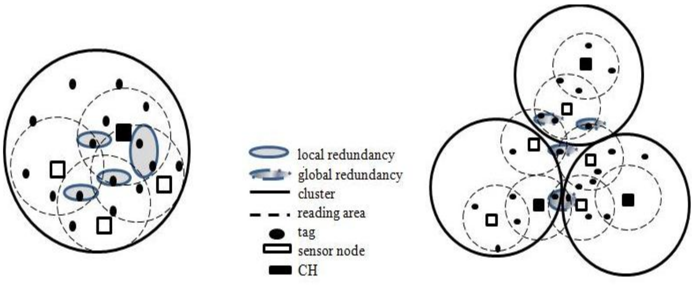
c) $| Ts_i - Ts_j | \leq \Delta$, where Δ is the time threshold to be acceptable

In the cluster-based model, we consider two types of readings. A local reading and a global reading are produced by a local node and a global node, respectively. A local node refers to one that does not have the overlapped area with nodes which belong to other different clusters from its cluster. Of course, it has the overlapped area with nodes in the same cluster as its cluster, producing the local redundancy readings. A global node refers to one that does have the overlapped area with nodes which belong to other distinct clusters, producing the global redundancy readings.

Definition 2 (***A local node and a global node***): Let $SN_i = \{N_j, i \in 1, 2, \ldots.n, j \in 1, 2, \ldots.n, \ i \neq j\}$ be a set of nodes that response to the enquiry of a node N_i. CI_i and CI_j denote the cluster identifier of a node N_i and N_j, respectively. A node N_i is a local node if $CI_i = CI_j$ holds for all j. Otherwise, it is a global node.

Redundant readings occur when reading ranges of different nodes are overlapped. Redundant readings are classified into local redundant readings and global redundant readings as shown in Figure 2. Local redundant readings are ones among local nodes, whereas global redundant readings are ones among global nodes. The tag data read by a node is delivered to its CH, and then CH checks whether tag data is redundant or not. The local redundant data can be locally detected and removed at its CH through some filtering process. This is possible because CH can have the knowledge of all local redundant readings within its cluster.

The global redundant data, however, cannot be obviously detected at its CH because CH can have no idea of other global redundant readings originated from nodes involved in different clusters. The other global redundant readings by nodes in different clusters must have delivered to their respective CH. As a result, the CH has no choice but to transmit the redundant data to next CH along the routing path. This evidently incurs redundant transmission that entails energy consumption and communication delay. This redundant transmission stops at last only after some distant CH on the routing path happens to detect the global redundancy. In other words, the transmission of redundant data continues at all intermediate CHs, traversing along the routing path until redundancy is detected at one of the intermediate CHs. Moreover, the intermediate CHs have to put up with computation overhead to check the possible global redundancy. Since global redundant readings are likely to increase in accordance with increased tags and degree of dense deployment of nodes, to devise an efficient scheme for checking global redundancy in advance without traverse is fundamental to the improvement of overall system performance.



(a) Local redundant readings (b) Global redundant readings

Figure 2: Two types of redundant readings

As an example, consider Figure 3. Assume that CH1 and CH2 have the global redundant readings for the same tags due to the overlapped reading range of nodes that belong to the different cluster 1 and cluster 2. The redundant global reading data at CH1 arrives at the intermediate CH10 through CH3, CH6 and CH9 along the routing path, while the redundant global reading data at CH2 also arrives at CH10 through CH4 and CH8 along the routing path. Now, the global redundancy can be detected at CH10 at the expense of the duplicate transmission of redundant data, leading to the energy consumption and communication delay in many intermediate CHs. Moreover, the intermediate CHs have to execute the filtering process to find out the incoming redundant global data to them. Those executions are in fact useless in that redundancy cannot be detected at such CHs because the redundant data are traversed along the different routing paths. Eventually, the attempts to run the filtering process also contribute to the wasteful consumption of energy.

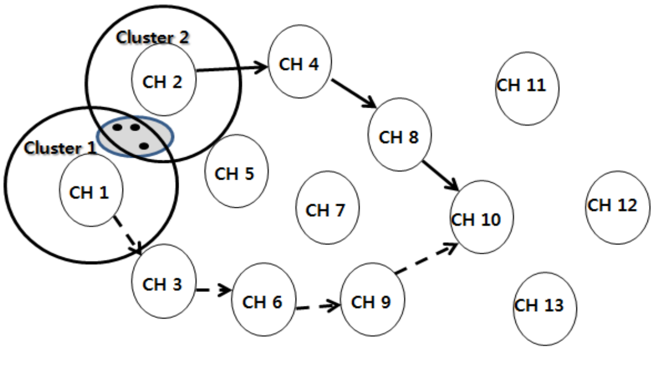


Figure 3: Detection of global redundancy readings at distant CH

On the other hand, it may be worthy of notice that tag data sent by a global node can also have the possibility of local redundancy. This fact makes it difficult to detect the redundancy generated by a global node, since CH cannot distinguish the local redundancy and global redundancy by the same global node. This implies that a scheme to consider this situation needs to be devised for eliminating the global redundancy. Figure 4 illustrates this. A global node can also have the overlapped areas with one or more its local nodes, which implies that tag data by a global node may have a local redundancy and/or global redundancy.

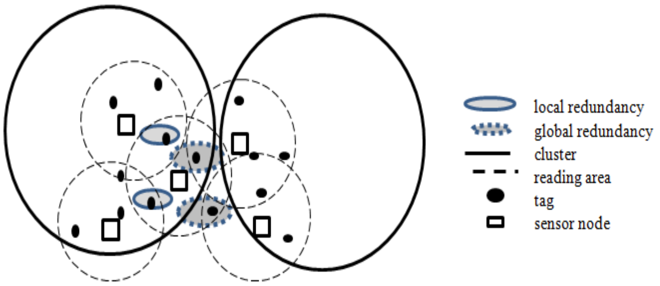


Figure 4: Local redundancy and global redundancy by one node

2-PHASE AGGREGATION SCHEME (2PA)

To minimize the undesirable overhead, it is necessary to detect the global redundancy without traversing the intermediate CHs along the routing path. We think the best way is, at the very beginning, to detect global redundancy at one of CHs which are associated with the global redundancy. In this section, we present the cluster head aggregation scheme called 2PA in our previous work [36].

Determining Node Type

To detect global redundancy, it is certainly necessary to exchange knowledge about global readings among global nodes. As a result, we need to know whether a node is a local node or a global node. To determine the node type, a node communicates with its surrounding nodes to obtain their cluster identifier. The surrounding nodes may belong to the same cluster as a node, or belong to the different cluster. If all surrounding nodes are exactly discovered, in our approach the unnecessary transmission of redundant data can be minimized to the highest level. However, even if some surrounding nodes are missing for some reasons, our approach is sufficiently reasonable because most of global redundancy seems to be detected without traversing along the routing path. The exact discovery of surrounding nodes is not a problem of correctness, but is a matter of efficiency degree in relation to unnecessary data retransmission. That is, it is deeply related with minimization level of unnecessary overhead.

In our approach, as one of tasks for system configuration after cluster establishment among nodes, each node sends an enquiry messages to its surrounding nodes in order to figure out their cluster identifiers. When a node receives such an enquiry message, it gives an answer with its node identifier plus its cluster identifier, <N_{id} *CI*>. Once a node receives answers from its surrounding nodes, according to *Definition 2*, it can determine whether it is a local node or not. If all cluster identifiers received from its surrounding nodes are same as its own cluster identifier, it becomes a local node. Otherwise, it becomes a global node. It is obvious that the answering surrounding nodes with different cluster identifiers are also global nodes and other answering surrounding nodes are local nodes. We define the answering nodes with different cluster identifiers to be direct surrounding global nodes of the enquiring node (*Definition 3*). Note that if a node A is a direct surrounding node of a node B, a node B is also a direct surrounding node of a node A. After determining the node type, each global node can keep the information about its direct surrounding global nodes and their clusters.

Definition 3 (***A direct surrounding global node)***): The global node that responds to the enquiry of a node N is defined to be a direct surrounding global node of node N.

To show an example, consider Figure 5. Each node receives answers from its surrounding nodes as follows.

Node A: [<B,CH2>, <D,CH3>]   Node B: [<A,CH1>, <C,CH2>, <D,CH3>, <E,CH2>]

Node C: [<B, CH2>, <E, CH2>]   Node D: [<A,CH1>, <B,CH2>]

Node E: [<B,CH2>, <C,CH2>]

Global nodes are A, B, and D since they have surrounding nodes with different cluster identifiers from their own cluster identifiers, respectively. Other nodes C and E are local nodes. Now, global nodes can keep the information of its direct surrounding global nodes such as node identifiers and cluster identifiers as follows.

Node A: [<B,CH2>, <D,CH3>]

Node B: [<A,CH1>, <D,CH3>]

Node D: [<A,CH1>, <B,CH2>]

Note that one global node can become a direct surrounding global node of several different global nodes with different clusters. For example, in figure 5, we can know that a global node B becomes two different global node A and D with different clusters.

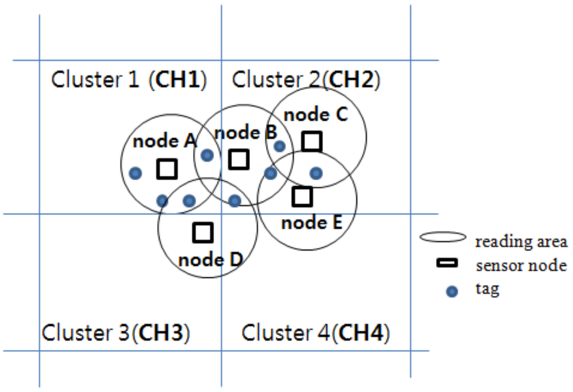


Figure 5: Sample configuration of clusters

Aggregation Scheme

When a node sends tag data to its CH, it attaches its determined node type to tag data. So, tag data consists of 4 fields including the additional field *Ntype*: *d(Tid, Ntype, Nid, Ts)*. *Ntype* has one value of 'L' and 'G', representing local node type and global node type, respectively. Based on the node type, CH can distinguish the local redundancy from the global redundancy. Hence, CH performs its function to deal with tag data, depending on the node type. It can detect local redundancy with its own knowledge. However, to check and detect global redundancy, it requires the global knowledge of tag readings from its direct surrounding global nodes. To get the needed global knowledge, it should communicate with other CHs of its direct surrounding global because those CHs have the knowledge of global tag readings generated by their direct surrounding global nodes.

It is very important to realize that surrounding global nodes of a global node can belong to different clusters from each other. In Figure 5, a global node A have overlapped reading areas with other global nodes <B, D> which belong to different clusters from each other. Similarly, the global node B has overlapped reading areas with other global nodes <A, D>. Finally, the global node D has overlapped reading areas with other global nodes <A, B>. Since each global node sends tag data to its CH, in order to detect the global redundancy, CH requires tag data read by surrounding global nodes. As an example, if CH1 has the knowledge of other global readings by global nodes B and D, it can detect the global redundancy among A, B, and D. Similarly, CH2 and CH3 also detect the global redundancy among A, B, and D by communication with each other. Consequently, CH1, CH2, and CH3 form one group which we call an aggregation of CH for a global node. Note that, since local redundancies can be detected by CH without communication with other CHs, aggregation needs to be built for only global nodes. Furthermore, one aggregation is needed for each global node.

An aggregation for a global node consists of cluster identifiers of its surrounding global nodes. In the above example, global node A, B, and D happens to have the same aggregation, <CH1, CH2, CH3>. Through communication among only CHs appeared in the aggregation, each CH can detect the global redundancy. The fundamental motivation of introducing the notion of aggregation for a global node is, at the beginning before traversal for detecting global redundancy, to confine communication overheads to only CHs in which its direct surrounding global nodes are involved. In the above example, communication among CH1, CH2, and CH3 is evidently more efficient for detecting global redundancies among global node A, B, and D, compared to sending global redundant tag data to other CHs besides CH1, CH2, and CH3. As you know, sending global redundant data to other CHs can result in undesirable transmission and computation costs because detection of global redundancy is likely to be impeded until some another CH on the routing path happens to have the needed global redundant tag readings.

On the other hand, if associated direct surrounding global nodes have the same aggregation, in order to detect the global redundancy, there is no need for each CH appeared in the aggregation to send its global readings to each other. It is sufficient for one of CHs to have knowledge of total global readings. Therefore, one of CHs appeared in an aggregation needs to be designated as a master head node (MH). For example, in Figure 5, global nodes A, B, and D happen to have the same aggregations <CH1, CH2, CH3>. If one of CH1, CH2, and CH3 is designated as a MH, then other CHs send its global readings to MH at which detection of the global redundancy is attempted and the global redundancy can be detected if there exists.

In relation to the aggregations for associated direct surrounding global nodes, it is very important to notice that each direct surrounding global node should have the same aggregation. Otherwise, CH is likely to incur undesirable anomaly when it sends global readings to the designated MH. In Figure 5, global nodes A, B, and D happen to have the same aggregation <CH1, CH2, CH3>. Unfortunately, the initial aggregations of associated direct surrounding global nodes are not always same. This occurs because a global node has overlapped area with one more global nodes involved in different clusters. To demonstrate the undesirable anomaly when surrounding global nodes does not have the same aggregation, consider Figure 6. The initial aggregations for node A, B, C, and D are as follows:

Node A: <CH1, CH2, CH3>
Node B: <CH1,CH4,CH2>
Node C: <CH1, CH3>
Node D:<CH2, CH4>

If CH receives aggregations like the above, CH cannot determine where it sends the global readings. This occurs because a global node has overlapped area with one more global nodes involved in different clusters. For example, node A is overlapped area with both node B and C which belong to different clusters, cluster 2 and cluster 3. As a result, to detect global redundancies among node A, B, and C, assume that CH1 is a MH. In this case, CH2 and CH3 must send respective global readings generated by node B and node C. CH2 also sends other global readings of B which overlapped with node D to MH (CH1). Unless CH4 for node D sends its global readings which also overlapped with node B to CH1, global redundancy between node B and node D cannot be detected at this stage. Note that <CH1, CH4, CH2> and <CH2, CH4> are aggregations of node B and node D, respectively. This demonstrates that each associated direct surrounding global node should have the same aggregation in order to prevent this undesirable anomaly. To build the same aggregations for associated direct surrounding global nodes, it needs to consider the transitive surrounding relationships among direct surrounding global nodes (*definition 4*). Note that the fact that a node A is a transitive surrounding node of a node C implies that a node C is also a transitive surrounding node of a node A.

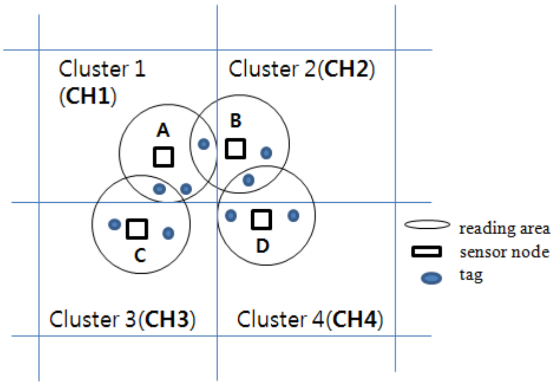


Figure 6: Transitive surrounding relationships of global nodes

Definition 4 (***A transitive surrounding global node)***: If a node A is a direct surrounding global node of a node B, and a node B is a direct surrounding global node of a node C, then a node A is defined to be a transitive surrounding global node of a node C.

Definition 5 (***An aggregation for a global node)***: An aggregation for a global node consists of cluster identifiers of its all direct and/or transitive surrounding global nodes including its cluster identifiers.

Our 2PA scheme consists of 2 phases. In the first phase, the initial aggregation for each global node is built. Each node sends an enquiry message to its surrounding nodes. On receiving the enquiry message, each surrounding node responds by sending an answer message including its node identifier and cluster head identifier. Each node determines its direct surrounding global node from answers and its node type can be also determined. From the answers from the direct surrounding global nodes, the first initial aggregation for each global node, can be built. To build the same aggregations among associated direct surrounding global nodes, a second-round communication begins in the second phase.

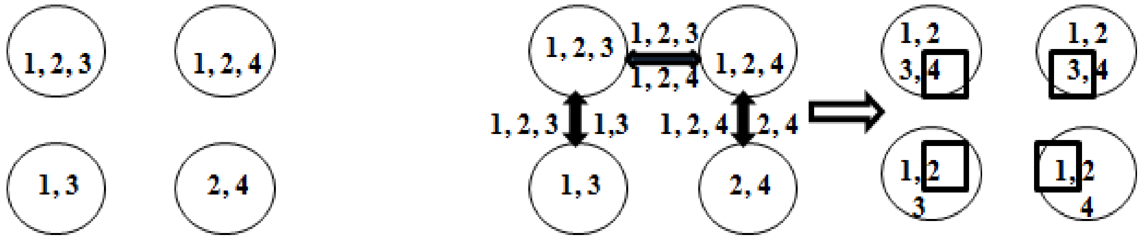
In the second phase, each global node sends its own current aggregation to its direct surrounding global nodes. On receiving the other aggregations from its direct surrounding global nodes, each global node combines its current aggregation with other aggregations received from its direct surrounding global nodes by eliminating the duplicate cluster head identifiers. If the current aggregation is subset of the new built aggregation, it means that there must have been also some other transitive surrounding global nodes which belong to different clusters from those which appear in the current aggregation. Then, the global node should send its new built aggregation to its direct surrounding global nodes in order to propagate the transitive relationships. On receiving the additional aggregations, each global node again makes a combined new aggregation. Now, the second-round communication ends. If any new aggregation is built again on the second round communication, then similarly third-round communication begins by sending the new current aggregation to their direct surrounding global nodes. The next round communication may continue until no more newly built aggregation exists. In the long run, each direct or transitive surrounding global nodes can have the same aggregation.

To take an example, consider again Figure 6. The initial aggregations for each global node are formed in the first phase as follows (Figure 7-a).

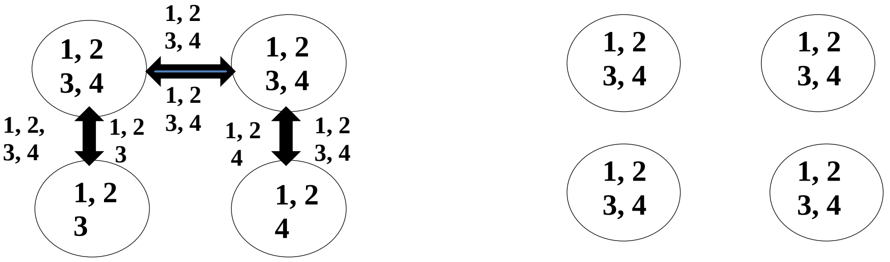
Node A: <CH1, CH2, CH3> Node B: <CH1, CH4, CH2>

Node C: <CH1, CH3> Node D: <CH2, CH4>

In the second phase, each node sends its initial aggregation to its surrounding nodes. Then, each node makes a temporary aggregation by unification (Figure 7-b). Then, it sends its initial aggregation to the nodes whose CHs newly appear in the united temporary aggregation (Figure 7-c). Again, each node makes a temporary aggregation, <CH1, CH2, CH3, CH4>, which is the final aggregation in this example (Figure 7-d).



(a) Initial aggregations **(b)** New built aggregations



(c) Sending to direct surrounding nodes (d) Final aggregations

Figure 7: Sketches of 2PA scheme

Proposition 1: 2PA guarantees the same aggregation among global nodes with direct and/or transitive surrounding relationships

< *proof* > Suppose that there are n global nodes G_1, G_2,…, G_n (n>1) which belongs to the different clusters whose cluster heads are CH_1, CH_2,…., CH_n, respectively.

- Case 1: N=2

In this case, two nodes must be a direct surrounding relationship between them. Therefore, it is obvious that they have the same aggregation consisting of their CHs.

- Case 2: N=3

Let 3 nodes be G_{i-1}, G_i, and G_{i+1} ($1<i<n$).They have either only direct surrounding relationships or both of direct relationship and transitive relationship among them. In case only the direct surrounding relationships among them exist, each node has the direct relationships with other two nodes. Therefore, it is obvious that they have the same aggregation consisting of their CHs. For a transitive relationship among them, one node must have the direct surrounding relationship with other two nodes. Assume that G_i has the direct surrounding relationships with G_{i-1} and G_{i+1}. Therefore, $G_{i-1}$and G_{i+1} have the transitive surrounding relationships through G_i. In the 1st phase, G_{i-1}, G_i, and G_{i+1} have the initial aggregations <CH_{i-1}, CH_i>, <CH_{i-1}, CH_i, CH_{i+1}>, and <CH_i, CH_{i+1}>, respectively. In the first round in the 2nd phase, each node sends its initial aggregation to its direct surrounding global nodes. Owing to the first round, G_{i-1} and G_{i+1} get to build the new aggregation <CH_{i-1}, CH_i, CH_{i+1}> and <CH_{i-1}, CH_i, CH_{i+1}>, respectively. Note that the aggregation for G_i have no change. Eventually, all nodes with both types of surrounding relationship can have the same aggregation <CH_{i-1}, CH_i, CH_{i+1}>.

For the generalization, we make m (n=3*m) virtual global nodes V_1, V_2……V_m. According to Case 2, three global nodes in each virtual node can have the same aggregation. Consider some two virtual nodes V_s and V_t (s, t$\in 1, 2 \dots m, s \neq t$) which contain 3 global nodes [G_{s-1}, G_s, G_{s+1}] and [G_{t-1}, G_t, G_{t+1}], respectively. Suppose that V_s and V_t get to have the direct surrounding relationships. This is possible if only one global node in V_s gets to have the direct surrounding relationship with only one global node in V_t. Let G_s and G_t be those global nodes. According to Case 1, through the additional-round communication, G_s and G_t build the new same aggregation. Then, according to Case 2, G_{s-1}, G_s, and G_{s+1} have the same aggregation, while G_{t-1}, G_t, G_{t+1} also have the same aggregation. After all, all global nodes in G_s and G_t can have the same aggregation. It is obvious that this is true even if there are one more direct surrounding relationships among global nodes in G_s and G_t. In this case, the only difference consists in the number of round communication needed to obtain the same aggregation. The same way can be applied to the remaining virtual nodes recursively. This fact demonstrates that all global nodes can have the same aggregation. ■

It is worthy of attention to consider the worst case in 2PA scheme. The worst case is to have numerous successive transitive surrounding relationships among global nodes. Consider Figure 8. Since each node has a successive transitivity, according to 2PA scheme, the final aggregation for each global node would include all cluster identifiers after several round communications in the second phase. In the worst case, the result is equivalent to that of other schemes which do not introduce the notion of aggregation. However, since there are generally a number of nodes in one cluster and the reading scope is noticeably narrow as compared with the cluster area, we think such successive transitivity is very unusual and unrealistic

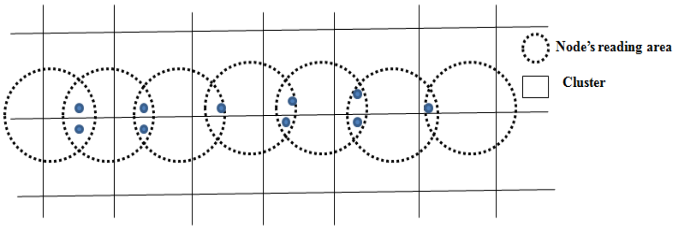


Figure 8: Successive transitive surrounding global relationships

DETECTION OF GLOBAL REDUNDANCIES

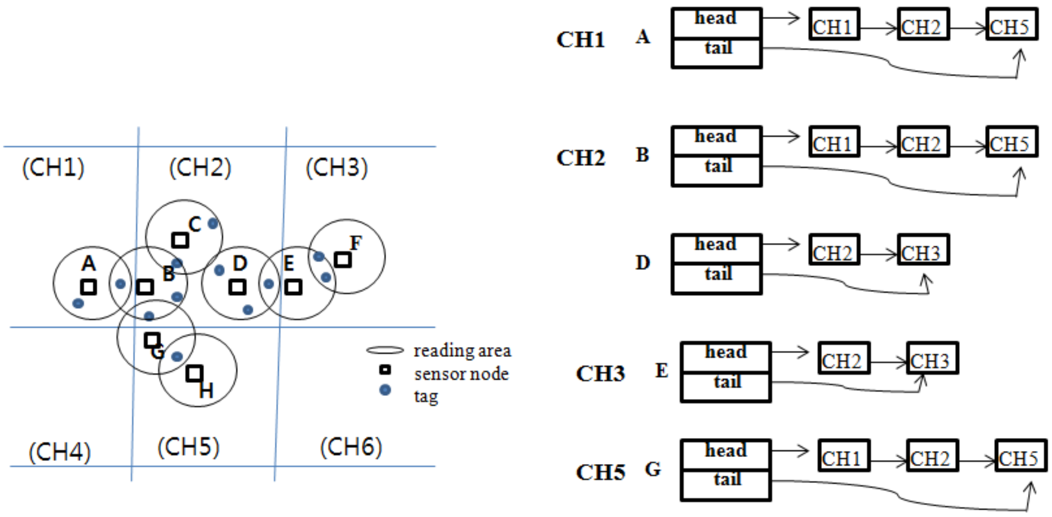
In our scheme, each CH maintains two main data repositories to store information for detecting redundancy. A tag table consists of tag entries *d(Tid, Ntype, Nid, Ts)* to which CH refers in order to check both the local redundancy and the global redundancy. Each CH maintains tag entries for tag data delivered to it. An incoming tag data is turned out to be a redundant tag data if it matches with any entry in tag table according to conditions in *Definition 1*. The discussion of efficient methods to check the redundancy is out of our scope, and as introduced in Section 1, many works related to the issue already exist. In addition, since discussion about implementing tag table efficiently is also out of our main purposes, we do not deal with the related mechanisms to exploit known techniques such as indexing, hashing, bit map, pruning table, and so on. Needless to say, the above issues can be separate research issues.

Master Cluster Head (MH)

According to 2PA scheme, surrounding global nodes ultimately get to have the same aggregation. Therefore, instead of sending global readings to each other, it is reasonable for one of CHs appeared in the aggregation to have total global readings. This node is designated as a master head node (MH) for the global nodes involved in the aggregation. Hence, each global node sends its aggregation to its CH. If CH receives the aggregation for a global node, it stores the aggregation into another repository called an aggregation list. An aggregation list is maintained for each global node in some order according to the cluster identifiers. The primary role of MH is to check the global redundancy. On behalf of global nodes, since every other CH which appear in an aggregation sends global readings to MH, MH gets to have knowledge of all global readings by global nodes. In pursuit of balanced power consumption, the role of MH may rotate among CHs. There may be several strategies. For example, CH with the longest-remaining power may be selected as next MH. Every CH may take over the role during its time quantum assigned to it. Time quantum for each CH may be also fixed or varied in length.

Without losing the main purpose of minimizing the redundant transmission, in this section, we address an illustrative strategy. We may choose round-robin rotation. Each CH has its time quantum which is a small unit of time, and time quantum is assigned on the basis of the number of nodes included in the cluster. That is, time quantum is inversely proportional to the number of nodes. The smaller time quantum is assigned to CH with more nodes. Initially one of CHs in an aggregation plays the role of MH. Since each CH is probably to participate in several aggregations for its global nodes, from the beginning, it is also possible to distribute the roles of MH among them. After expiration of time quantum, CH declares the end of role to other CHs in the aggregation. Then, the next CH takes over the role of MH. To support the round-robin scheme, the aggregation list is implemented as a linked list as shown in Figure 9.

In Figure 9-a, global nodes are A, B, D, E, and G. According to 2PA scheme, nodes A, B, and G have the same aggregation [<CH1>,<CH2>,<CH5>], whereas nodes D and E also have the same aggregation [<CH2>,<CH3>]. Figure 9-b shows the illustrative implementation of aggregation lists. Each CH maintains aggregation list of its global nodes. For example, CH2 maintains two aggregation lists for global nodes B and D. The head pointer and tail pointer point to the first node and the last node, respectively. The node pointed by head pointer plays the role of MH. Initially, CH1 plays the role of MH for the global nodes A, B, and G, while CH2 plays the role of MH for the global nodes D and E. As an example, if time quantum of CH1 expires, it informs CH2 and CH5 of the fact. Then, CH1, CH2, and CH5 delete the first node and attach it to the last node, adjusting the corresponding pointers. So CH2 becomes the new MH.



(a) Illustrative sample of configuration (b) Linked list implementation

Figure 9: Aggregation list implemented as a linked list

Detection Scheme

In ASER, tag data received by a particular CH usually originates from two major sources. Since every node sends its tag data to its CH, both local nodes and global nodes are one of sources. Other CHs are another sources, since other CHs send tag data due to participation in aggregation or just forwarding the non-redundant data towards next CH along the routing path. Incoming tag data from other CHs due to participation in the aggregation should be checked whether it is globally redundant or not. On the contrary, if the incoming tag data come from the CHs for forwarding, it must have already turned out to be non-redundant. Considering tag data from CHs with these two cases, we add additional two types of node, ‘A’ and ‘N’, to existing node type. Types ‘A’ and ‘N’ represent for tag data from CHs for participating in aggregation and forwarding non-redundant tag data, respectively. Note that types ‘L’ and ‘G’ represent for tag data from local nodes and global nodes, respectively.

When CH receives tag data, first of all, CH examines the node type attached to the incoming tag data. If node type is ‘N’, it just send the tag data to the next hop node without checking the redundancy, since tag data has already turned out to be non-redundant. Of course, it is not necessary to store the tag entry into tag table for later redundancy check.

In case node type is ‘L’, CH checks local redundancy of tag data by referring to the tag table. CH can make a decision about the redundancy according to the conditions in *Definition 1*. If redundancy is detected, it is sufficient for CH simply to discard the local redundant data. Otherwise, it just send tag data to the next hop node, after updating *Ntype* as ‘N’ and storing the tag entry, *d(Tid, Ntype, Nid, Ts)*, into the tag table for using local redundancy check later.

If node type is ‘G’, first of all, CH refers to the tag table in order to check local redundancy against tag data by its other local nodes. If CH detects redundancy, it simply discards the local redundant data. If CH does not detect the local redundancy, two cases to consider still remain. First, tag data from a global node happens to arrive at CH first before other local redundant tag data by local nodes arrive at CH. Second, the tag data may have the global redundancy with tag data read by global nodes belong to different clusters. Consider Figure 10. Node B in cluster 1 is a global node overlapped with node C in cluster 2. Reading Tag 1 by node B may have a local redundancy with reading Tag 1 by a local node A. At the same time, reading Tag 2 by node B may have a global redundancy with reading Tag 2 by a global node C. If reading Tag 1 by node B arrives at CH1 before reading Tag 1 by node A arrives, CH1 decide the reading Tag 1 by node B as non-redundant data. In this case, tag entry of Tag 1 by node B should be stored into tag table for checking the local redundancy with reading Tag 1 by node A. Then, it should be sent to the next hop node. In contrast, CH1 sends reading Tag 2 by node B to CH2 (if it is a MH) because reading Tag 2 by node B has global redundancy with reading Tag by node C. Moreover, storing tag entry of Tag 2 by node B is not needed because the global redundancy is checked at its MH.

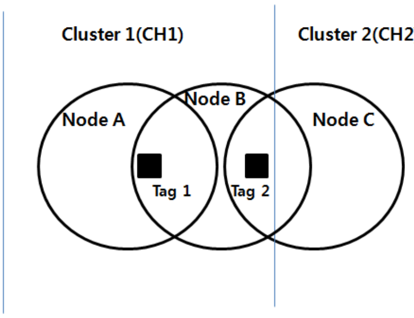


Figure 10: Difficulties in readings of a global node

The above example demonstrates that two cases require different mechanisms for redundancy check. Unfortunately, however, it is impossible to distinguish the two cases generated by the same global node unless there is some additional knowledge about tag such as tag location. If we can know additionally whether overlapped area occurs due to nodes in the same cluster or not, it is possible to distinguish two cases. For example, if we know that Tag 1 is located in the overlapped area between a local node A and a global node B, we can decide that reading Tag 1 by global node B have only local redundancy. However, we think that maintenance of such knowledge is impractical, even simply considering the huge number of tags in the systems. Therefore, in this paper, we treat two cases without distinguishing them. In either case, CH stores the tag entry into the tag table for using redundancy check later, then sends tag data to MH for the global node.

In order to identify MH, CH examines the front node of aggregation list for the global node because the front node pointed by a head pointer is MH. Therefore, CH can know whether it is a MH or not. If it is not a MH, it first updates *Ntype* as ‘A’, and stores the tag entry into the tag table. Updating *Ntype* as ‘A’ is an important prerequisite to sending tag data to MH. This makes it possible for MH to recognize the need for global redundancy check among readings by global nodes associated with the aggregation. Next, CH should send tag data with type of ‘A’ to MH for the global node so that the tag data can be checked against the global redundancy at MH. If it is a MH, it should update *Ntype* as ‘N’ and store the tag entry into the tag table for using redundancy check later. Then, it sends tag data to the next hop node.

Lastly, consider the case of node type ‘A’. The CH received tag data with type value of ‘A’ must be a MH for the corresponding global node. In the long run, the CH can have the total global readings by surrounding global nodes since other CHs also send the global readings to MH. Therefore, CH can check global redundancy.

ASER is outlined in Figure 11. As you figures out, in case of node type ‘G’, some cost may be paid instead of avoiding the impractical approach. That is, tag entries for readings by global nodes are likely to be stored both at a CH and MH, which may increase the maintenance overhead of tag table. In addition, tag data with no possibility of the global redundancy may be also unnecessarily sent to MH and then MH checks redundancy. However, an efficient scheme for pruning tag table can relive the overhead of tag table. Note that unnecessary sending and checking is performed just once. According to ASER, for example, in Figure 10 tag entry for Tag 2 by node B is stored at CH1 and CH2 (if CH2 is a MH). In addition, unnecessarily reading Tag 1 by node B is sent to CH2 (if CH2 is a MH) and checked for redundancy. Note that we pay some overhead for node type ‘G’ only when CH itself is not a MH.

```
while ( 1 ) {
Find NodeType from incoming tag data;
switch(NodeType) {
case ‘N’:
Send tag data to the next hop node;    //forwards to next hop
break;
case ‘L’:
case ‘A’:
Perform redundancy check;
if (is_redundancy(tag_data ))    // is_redundancy( ) returns 1 if redundant, otherwise returns 0
then Discard the tag data;
else {Update NodeType as ‘N’;    // non-redundant tag data
Store tag entry into tag table;
Send tag data to the next hop node;
    }
  break;
case ‘G’:
Perform redundancy check;   //for both local and global redundancy
if (is_redundancy(tag_data ))
then Discard the tag data;
else if (is_MH( ))    //is_MH( ) returns 1 if CH itself is MH, otherwise returns 0
then {Update NodeType as ‘N’;    // non-redundant local or global tag data
Store tag entry into tag table;
Send tag data to the next hop node;    //forwards to next hop
        }
else {Update NodeType as ‘A’;    //may need for global redundancy check at MH
Store tag entry into tag table; //may need for local redundancy check at CH itself later
Send tag data to MH for the global node;  //send to MH for global redundancy check
        }
  break;
}  // end while
```

Figure 11: Outline of ASER

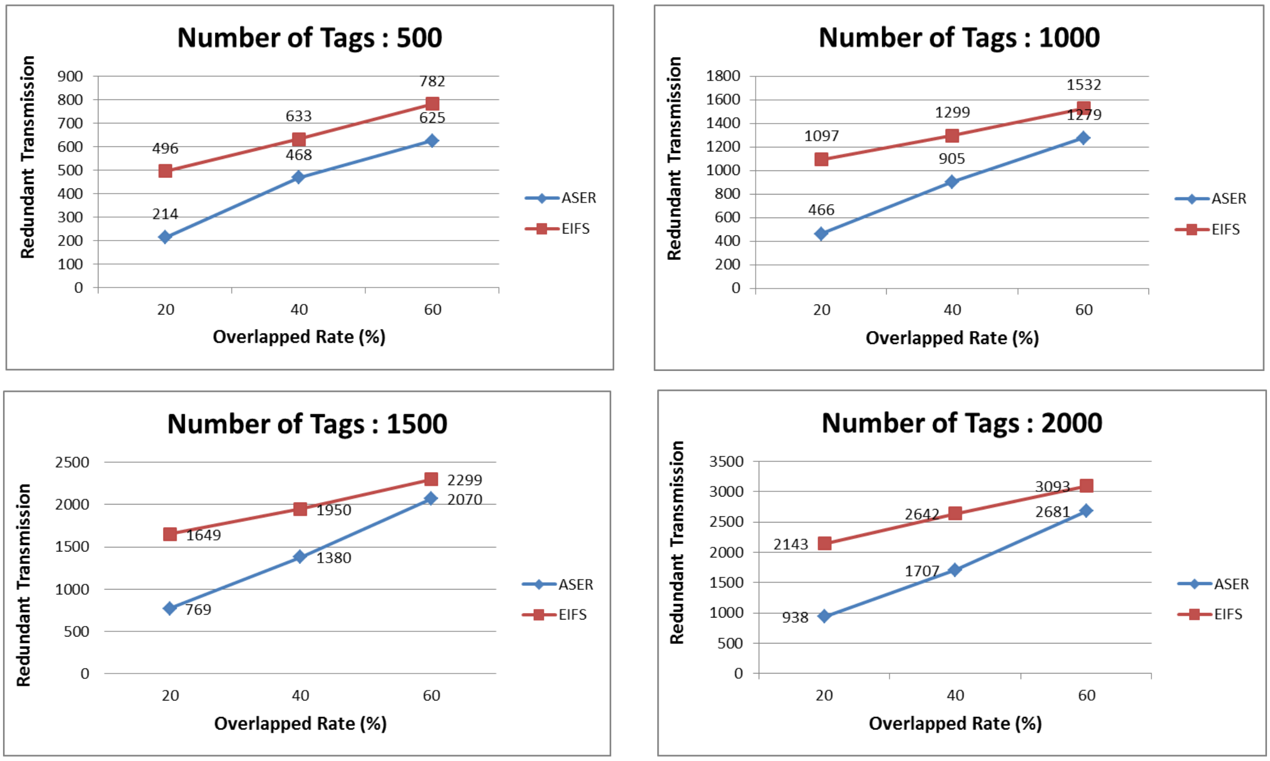
PERFORMANCE EVALUATION

Authors in [33] proved that EIFS performs better than INPFM [34] and CLIF [35] in terms of communication cost and computational overhead, saving power efficiently. To evaluate the performance of ASER, we compare ASER with EIFS through simulation approach. Since both redundant data transmission and redundancy checking contribute to the waste node power, we consider 2 measures for comparison: number of redundant transmission and number of redundancy checking. Table 1 shows parameters used for the simulation. Each cluster consists of the same number of nodes which are located uniformly in a cluster, whereas tags are distributed randomly over reading area of nodes. The overlapped ratio means the ratio of overlapped reading area among nodes.

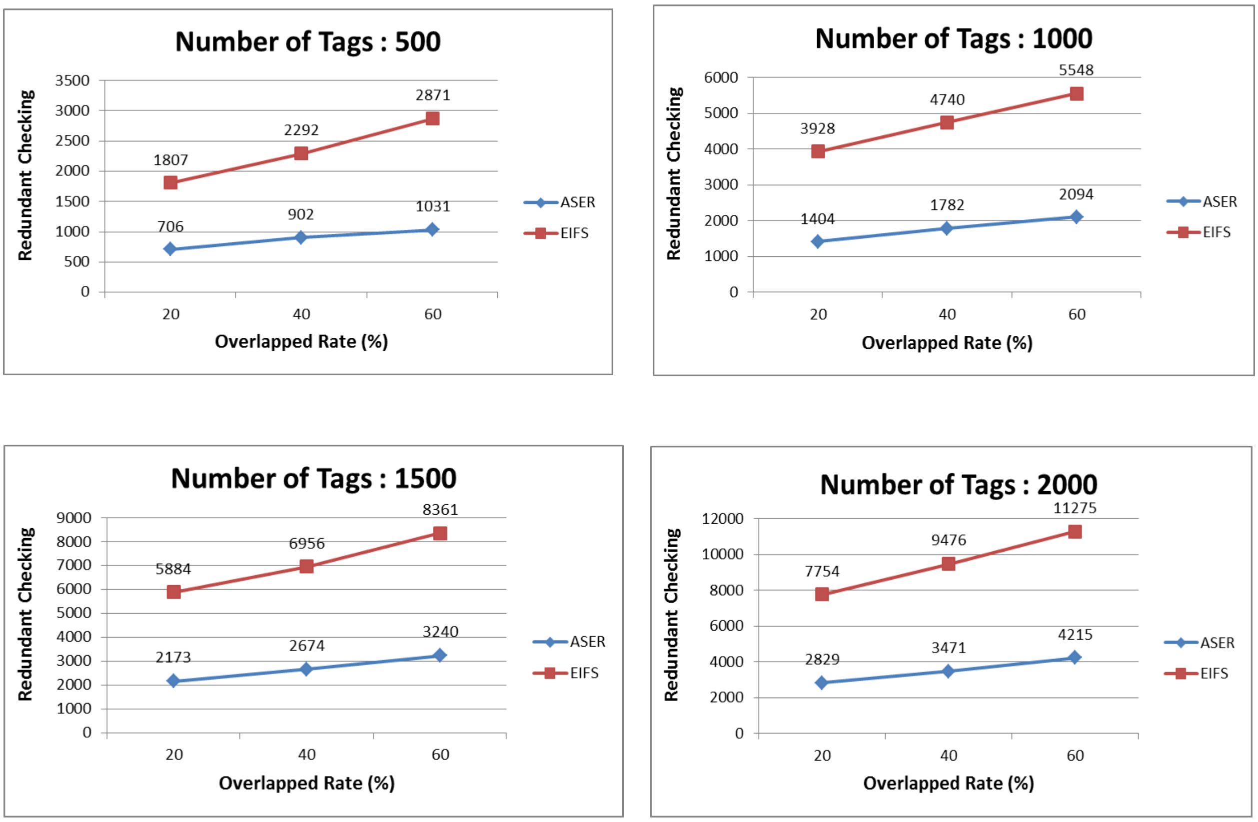
Table 1: Parameters of the simulation

Parameter	**Value**
clusters	25 (in number)
nodes per cluster	9 (in number)
overlapped ratio	20 ~ 60 (%)
tag	500 ~ 2000 (in number)

Figure 12 shows that ASER is better than EIFS in terms of redundant transmission and global redundancy checking for 4 cases with tag numbers of 500, 1000, 1500, and 2000. These results stems from the notion of aggregation with which ASER can detect the global redundancy at near CHs of surrounding global nodes without traversal. Figure 12(a) shows that, as the overlapped rate increases, the difference in the redundant transmission of ASER and EFIS inversely decrease. This owes the fact that the successive transitive surrounding global nodes also increase as the overlapped rate increases, which increases the number of CHs participated in one aggregation and makes the aggregation bigger. Note that the increased CHs in one aggregation need more transmission to their MH before global redundancy is detected at MH. This demonstrates that the notion of aggregation is effective in cluster-based redundancy detection scheme. In contrast, as the overlapped rate increases, the difference in redundancy checking also slightly increase (Figure 12(b)). This is a natural consequence because in our scheme the global redundancy is checked at MH instead of individual participating CH, though the number of participating CHs in one aggregation increases. In addition, as tags and overlapped ratio increase, both redundant transmission and redundancy checking also increase in both ASER and EIFS due to the increased possibility of both global and local redundancy. In short, ASER has more efficiency in power savings than EIFS especially in larger densely deployed networks.



(a) Redundant transmission



(b) Redundancy checking

Figure 12: Evaluation results

CONCLUSIONS

Since RFID and WSNs are complementary technologies, integration of two can contribute to implement smart and dynamic environments such as Internet of Things. To eliminate the redundancy helps to save the power consumption. In particular, since elimination of global redundancy needs to have knowledge about all global readings by surrounding nodes, it is very important to minimize redundant transmission and redundancy checking to detect the global redundancy. In this paper, we propose an aggregation-based low power scheme for eliminating redundancy in the integrated RFID and WSNs.

For developing ASER, we first introduce the notion of aggregation and then propose a 2-phase aggregation (2PA) scheme to build the aggregations for the global nodes. In the first phase, node type is determined and the initial aggregations for surrounding global nodes are drawn. Since aggregations for global surrounding nodes should be same, in the second phase the same final aggregations are drawn. In ASER, to eliminate global redundancy, one of CHs participated in the aggregation is designated as a master head node (MH). The MH can play the role of detecting global redundancy, since other CHs send their global readings to it. ASER can minimize the redundant transmission and redundancy checking of global redundant data, which contributes to prevention of wasteful power consumption.

We evaluate ASER to see how much ASER can reduce the communication cost and computation overhead, thereby savings the node power. Redundant retransmission and global redundancy checking are taken into consideration as measures for performance evaluation. According to simulation results, ASER considerably contributes to reduction in the undesirable overheads, as compared with previous related works. The contribution basically results from the notion of aggregation. That is, by detecting global redundancy at near CHs for surrounding global nodes instead of distant intermediate CHs along the routing path, ASER can avoid the redundant transmission cost and redundancy checking overhead.

REFERENCES

[1] Ahsan, K., Shah, H. and Kingston, P., 2010, “RFID Applications: An Introductory and Exploratory Study,“ International Journal of Computer Science, Vol. 7, pp. 1-7.

[2] Janiffer Y., Biswanath, M. and Dipak, G., 2008, “Wireless Sensor Network Survey,” Computer

Networks, Vol. 52, pp. 2292-2330.

[3] Borges, L. M., Velez, F.J. and Lebres, A.S., 2014, “Survey on the Characterization and Classification of Wireless Sensor Network Applications,” IEEE Communications Surveys and Tutorials, Vol. 16, pp. 1869-1890.

[4] Aggarwal, C. C. and Han, J., 2013, “A Survey of RFID Data Processing. Managing and Mining Sensor Data,” C. C. Aggarwal eds., Springer US, pp. 349-382.

[5] Derakhshan, R., Orlowska, M. E. and Li, X., 2007, “RFID Data Management: Challenges and Opportunities,” IEEE Int. Conf. on RFID, pp. 175-182.

[6] Garcia-Ansola, P., Garcia, A. and Morenas, J. Z., 2011, “Improving Visibility in Industrial Environments by Combining WSN and RFID,” Journal of Zhejing Univ. Science A (Applied Physics and Engineering), Vol. 12, pp. 849-859.

[7] Mark, L., McKelvin, Jr., Mitchel, L. W. and Nina, M. B., 2005, “Integrated Radio Frequency Identification and Wireless Sensor Network Architecture for Automated Inventory Management and Tracking Applications,” Proc. of the 2005 Conf. on Diversity in Computing.

[8] Mitrokotsa, A. and Douligeris, C., 2009, “Integrated RFID and Sensor Networks: Architecture and Applications,” Y. Zhang et al., eds., RFID and Sensor Networks, CRC press, pp. 511-535.

[9] Zhu, J. and Sun, N., 2011, “Research on Integration of WSN and RFID Technology for Agricultural Product Inspection. American Journal of Engineering Technology Research,” Vol. 11, pp. 2299-2305.

[10] Omar, S. and Mehedl, M., 2013, “Towards Internet of Things: Survey and Future Vision,” International Journal of Computer Networks, Vol. 5, pp.1-17.

[11] Tomas, S. L., Daeyoung, K., Gonzalo, H. C. and Koudjo, K., 2009, “Integrating Wireless Sensors and RFID Tags into Energy-Efficient and Dynamic Context Networks,” The Computer Journal, Vol. 52, pp. 240-267.

[12] Zhang, L. and Wang, Z., 2006, “Integration of RFID into Wireless Sensor Networks: Architecture, Opportunities and Challenging Problem,” Proc of 5th Int. Conf. on Grid Cooperative Computing Workshops, pp. 463-469.

[13] Gamba, G., Tramarin, F. and Willing, A., 2010, “Retransmission Strategies for Cyclic Polling over Wireless Channels in the Presence of Interference,” IEEE Transactions on Industrial Informatics, Vol. 6, pp. 405-415.

[14] Haase, J., Molina, J. M. and Dietrich, D., 2011, “Power-aware System Design of Wireless Sensor Networks: Power Estimation and Power Profiling Strategies,” IEEE Transactions on Industrial Informatics, Vol. 7, 2011, pp. 601-613.

[15] Wang, L., L. D., Xu, Bi Z. and Xu, Y., 2014, “Data Cleaning for RFID and WSN Integration,” IEEE Transactions on Industrial Informatics, Vol. 10, pp. 408-418.

[16] Chen, H., Ku, W. S., Wang, H. and Sun, M.T., 2010, “Leveraging Spatio-Temporal Redundancy for RFID Data Cleansing,” ACM SIGMOD Conference, pp. 51-62.

[17] Jeffery, S. R., Garofalakis, M. and Franklin, M. J., 2008, “Adaptive Cleaning for RFID Data Streams, ” VLDB Journal, Vol. 17, pp. 265-289.

[18] Liao, G., Li J., Chen, L. and Wen, C., 2011, “KLEAP: An Efficient Cleaning Method to Remove Cross-Reads in RFID Data Streams,” ACM CIKM(Conf. on Information and Knowledge Management), pp. 2209-2212.

[19] Mahdin, H. and Abawajy, C., 2011, “An Approach for Removing Redundant Data from RFID Data Streams,” Sensors, pp. 9863-9877.

[20] Massawe, L. V., Vernaak, H. and Kinyua, J. D. M., 2012, “An Adaptive Data Cleaning Scheme for Reducing False Negative Reads in RFID Data Streams,” IEEE Int. Conference on RFID, pp. 157-164.

[21] Shin, D., Oh D., Ryu, S. and Park, S., 2014, “A Smoothing Data Cleaning based on Adaptive Window Sliding for Intelligent RFID Middleware Systems,” Journal of Intelligence and Information Systems, Vol. 20, 2014, pp. 1-18.

[22] Bashier, A. K., Lim, S. J., Hussain, C. S. and Park M. S., 2011, “Energy Efficient In-network RFID Data Filtering Scheme in Wireless Sensor Networks,” Sensors, pp. 7004-7021.

[23] Choi, W., Eric, N. and Wendy, T., 2008, “The Tag Duplication Problem in an Integrated WSN for RFID-based Item-level Inventory Monitoring,” Int. Conf. on Networked Sensing System, pp.59-62.

[24] Hairulnizam, M. and Jemal, A., 2011, “An Approach for Removing Redundant Data from RFID Data Streams,” Sensors, pp. 9863-9877.

[25] Hongli, D., Zidong, W., Steven, X. D. and Huijiun G., 2014, “A Survey on Distributed Filtering and Fault Detection for Sensor Networks,” Mathematical Problems in Engineering, pp. 1-7.

[26] Wang, L., Xu, L. D., Bi, Z. and Xu, Y., 2014, “Data

Cleaning for RFID and WSN Integration," IEEE Transactions on Industrial Informatics, Vol. 10, pp. 408-418.

[27] Xiaowei, W., Qiang, Z. and Yan, J., 2008, "Efficiently Filtering Duplicates over Distributed Data Streams," Int. Conf. on Computer Science and Software Engineering, pp. 631-634.

[28] Elena, F., Michele, R., Jorg, W. and Michele Z., 2007, "In-Network Aggregation Techniques for Wireless Sensor Networks: a Survey," IEEE Wireless Communications, Vol. 14, pp. 70-87.

[29] Weifa, L. and Yuzhen, L., (2007, "Online Data Gathering for Maximizing Network Lifetime in Sensor Networks," IEEE Transactions on Mobile Computing, pp. 2-11.

[30] Ali, K. B., Hassanein, H. S. and Alsalih, W., 2011, "Using Neighbor and Tag Estimations for Reductions for Redundant Reader Eliminations in RFID Networks," Proc. of IEEE Wireless Communications and networking Conference, pp. 832-837.

[31] Irfan, N. and Yagoup M. C. E., 2010, "Efficient Approach for Redundant Reader Elimination in Large-Scale RFID Networks," IEEE Int. Conf. on Integrated Intelligent Computing, pp. 102-107.

[32] Meng, M., Ping, W. and Cho, H. C., 2013, "A Novel Distributed Algorithm for Redundant Reader Elimination in RFID Networks," IEEE Int. Conf. on RFID-Technologies and Applications, pp. 1-6.

[33] Ali, K. B., Lee, S. J., Chauhdary S. H. and Park M. S., 2011, "Energy Efficient In-network RFID Data Filtering Scheme in Wireless Sensor Networks," Sensors, pp. 7004-7021.

[34] Choi, W.I. and Park, M. S., 2007, "In-Network Phased Filtering Mechanism for a Large-Scale RFID Inventory Application," Proc. of 4th Int. Conf. on IT & Applications, pp. 401-405.

[35] Kim, D. S., Ali, K., Xue, M., Kim, J. H. and Park, M. S., 2008, "Energy Efficient In-Network Phase RFID Data filtering Scheme," Proc. of 5th Int. Conf. on Ubiquitous Intelligence and Computing, pp. 311-322.

[36] Shin, D. C. and Park, S. K., 2016, "A Cluster Head Aggregation Scheme for Early Elimination of Global Redundancy In a Cluster-based Model of Integrated RFID and Wireless Sensor Networks," International Journal of Applied Engineering Research, Volume 11, Number 15, pp. 8631-8640.

[37] Abdulrahman, A., Ashraf, E. A., Sharief, M. A. O. and Hossam, S. H., 2013, "Selective Context Fusion Utilizing an Integrated RFID-WSN Architecture," 10th Annual IEEE-CCNC Smart Spaces and Sensor Networks, pp. 317-322.

[38] Cho, J., Shim, Y., Kwon, T., Choi, Y., Pack, S. and Kim, S., 2007, "SARIF: A Novel Framework for Integrating Wireless Sensor and RFID Networks," IEEE Wireless Communication, Vol. 14, pp. 50-56.

[39] Hai, H., Miodrag, B., Amiya, N. and Ivan, S., 2008, "Taxonomy and Challenges of the Integration of RFID and Wireless Sensor Networks," IEEE Network, Vol.22, pp. 26-32.