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# Energy Efficient Approach in RFID Network

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**Abstract.** Radio Frequency Identification (RFID) technology is among the key technology of Internet of Things (IOT). It is a sensor device that can monitor, identify, locate and tracking physical objects via its tag. The energy in RFID is commonly being used unwisely because they do repeated readings on the same tag as long it resides in the reader vicinity. Repeated readings are unnecessary because it only generate duplicate data that does not contain new information. The reading process need to be schedule accordingly to minimize the chances of repeated readings to save the energy. This will reduce operational cost and can prolong the tag's battery lifetime that cannot be replaced. In this paper, we propose an approach to minimize energy spent during reading processes. Experiments conducted shows that proposed algorithm contribute towards significant energy savings in RFID compared to other approaches.

## 1. Introduction

RFID is emerging as an automation tool for monitoring, tracking, locating and identifying physical objects tagged with its chip. It has been use in many areas including supply chain [1], healthcare [2], construction [3], wildlife [4] and farming [5]. It enables process improvement on the area where it turns tedious manual works into simplified automated process. For example, instead of scanning the barcodes manually, RFID can simultaneously read all the objects and return related data to the system in very short time [6]. The growth of RFID deployment has been exponential since its reintroduction in the late 90s. In 2006 the number of tags has been sold is three times bigger than over the previous 60 years [7]. In 2014, the total market value for RFID is \$9.2 billion and is expected to reach \$30.24 billion in 2024 [8].

Based on this market pattern and trajectory, it is expected that RFID will becoming the most common pervasive devices in our life. As the most widely used technology, we need an energy-savings mechanism to cut the system operational cost. Minimizing the usage also can prolong the devices lifetime which help businesses obtain longer return-on-investment period. In certain circumstances, such as deployment at a natural disaster place [9], energy savings conscience is very important as the energy resource were limited and hard to be renew. For example the use of active tag to detect trapped coal miners in the tunnel [10]. The evacuation need to be done quickly before the battery on the tag dried out.

In this paper we present how energy savings is achieved through efficient reader scheduling mechanism. The readers are schedule in a way that no adjacent reader will do reading at the same time. Based on this the risk of signal collision is reduce to zero and the need to repeat readings because of the collision can be avoided. The tag in the overlapped vicinity also can be read by only one reader



by locking the session only to that reader. Reducing the number of the readings some amount of energy could be saved from being wasted. This paper is organized as follows: section 2 describes \on related works, section 3 is the details on the algorithm, section 4 is on performance analysis and section 5 is the conclusion.

## 2. Background

Distributed Color Selection (DCS) and Variable-Maximum Distributed Color Selection (VDCS) or known as Colorwave is an approach to schedule reader to avoid signal collision among the adjacent readers [11]. The approach is distributed and is robust to new reader addition. It works by grouping the reader into different slot based on the number of their adjacent nodes. Only reader in the slot will be turn on when it is called. The other slot will be turn to sleep. However, if there is still collision, the reader need to called random generator to get new slot. The adjacent reader also needs to be assigned new slot. This is happening in the middle of reading process which will delay the system. Energy also is spent to give notice to other reader on the new changes. The method of assigning the slot to the reader is shown in Figure 1.

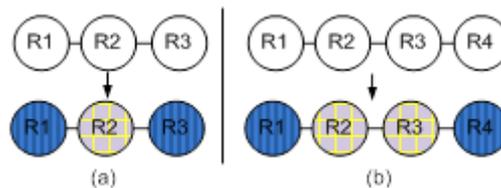


Figure 1. Three readers group into two slots based on DCS

In Figure 1(a) there are three adjacent nodes represent reader R1, R2 and R3. DCS will ‘color’ the nodes based on the number of adjacent nodes. R1 and R3 get the same color because both have one adjacent node. R2 have two adjacent nodes and get another color. When the system start R1 and R3 will start reading together and R2 will started in the new slot.

However there will be collision in cases as shown in Figure 1(b). R2 and R3 have the same number of adjacent nodes and were given the same color. When they started reading their signal will collide with each other. When this occur, the reader need to choose new color randomly. The other adjacent nodes also need to choose the new color. The number of slot might be more than two which is not good for the reading quality. A tag can get out from the system before it gets detected because waiting too long for the slot to take turns. The best approach is only to avoid by collision but not trade off the quality of readings. Colorwave, the extended version of DCS, minimize the number of color that the reader can choose off. This is to control the number of slot in the reader networks. However, it does not solve the problem of inaccurate slotting that cause the collision among the reader.

**Table 1.** List of Tag Id

Tag	ID
Tag 1	00010101000100
Tag 2	00100101101010
Tag 3	10101001101110
Tag 4	01010101000100

Collision also can happen not only among reader but also among tag. An approach to avoid collision is by using tree-based anti-collision approach [12]. Among the popular approach are Binary Tree (BT) protocol [13] and Query Tree (QT) [14]. The approach works by matching the tag ID bitwise where the tag can be read one by one. The process is known as singulation [15]. This feature is only available for EPC Global Gen2 RFID. For example we have 4 tags as listed in Table 1. If the reader start to find tag that begins with ‘0’ to respond, there are three tag which is Tag1, Tag2 and Tag3 will respond. The

signal from these tags cannot be differentiated by the reader, moreover it only wants to read one tag at a time. The reader then will ask tag that started with '00'. Two tag which is Tag1 and Tag2 will respond. The reader then will go for tag that start with '000', only one tag will respond which is Tag1. The reader will start communicating with this tag. After that it will communicate with this tag. After this tag the reader will go for tag that begins with '001' until it finishes all tag. This approach is effective but it takes time and has numbers of iteration to complete the reading process to finish. We need an approach that is simple and reliable in reading the tags with minimum energy consumption.

Another feature of Gen2 is tag session [16]. A tag can have up to four sessions where one tag can communicate with four readers simultaneously. This means the tag can differentiate every reader that is currently communicating with the tag. It can remember which reader has done with the communication and thus does not need to repeat it again until next cycle of readings. In this paper, we proposed a slotting approach called SELECT to save RFID reader's energy. Based on this approach, not all readers will be operating at the same time. Readers will take turns to read the tags and sleep to save energy. We also apply the use of session, where reader that has read all the tags in its vicinity does not have to do the reading again.

### 2.1.1 Energy Model

The energy consumption for RFID depends on the data size (bit), rate (kbps), time taken to transmit data and power supply. The time taken to transmit the signal can be calculated using Eq. (1):

$$T = \frac{ID}{rate} \quad (1)$$

where ID is the size of tag id and rate is the tag data rate. Energy can be calculated using Eq. (2):

$$E = (V \times I) \times T \quad (2)$$

where V (volts) is the power supply and I (amperes) is the current consumed during scanning.

There are three modes of operation for RFID: (i) scan (ii) idle and (iii) sleep. The highest energy consumption is while the reader is in the scan mode, follows by idle and then sleep mode. During sleep mode the reader will use a very little any energy. Wake up signal can be sent from the middleware to change the reader mode such as from sleep to scan mode.

Table 2 shows the current values for readers from different models including SkyeModule M8, SkyeModule M1 and SkyModule M1 Mini at different mode [17]. As we can see there are significant differences in current consumption between each mode. The current consumption during sleep mode is less than 1% during scan mode for each model. For idle mode the consumption it is about 10-25% from the scan mode.

To calculate the energy to read one tag, let say the data rate is 26kbps and power supply is 6 volts. Using the equation (1) and (2), the energy needed to read one tag with data size of 96 bits using the SkyeModule M1- Mini is 1.329 joules. Only one reading on the tag is needed. When the reader read the tag for the second time, it considered duplicates and wastes energy.

While putting the reader in sleep mode to save energy, one thing that need to take into account is the energy required to send wake up signal to the reader. The energy must not exceed the savings that we accumulate from the sleep mode compared to the energy used when the reader is idle. According to [18], the equation to calculate the energy to switch from sleep mode to scan mode is

$$E = \frac{(I_{active} - I_{sleep}) \times T \times V}{2} \quad (3)$$

The wake up signal does not contain any data, and the time to wake up SkyModule M1 Mini is 0.1 seconds [19]. Based on equation (3), the energy needed to wake up this reader is 0.035964 joule. If the reader is sleep for 10 minutes, the energy used is 0.18 joule. Therefore the amount for both activities which are sleep and switching mode is only 0.25964 joule. If the reader is left to be idle, the amount of energy used for ten minutes will be 54 joule. The savings we made for putting the reader into sleep mode is 99% of savings. The energy savings will be much more if there are tags to be read, and the readings are duplicates which really need to be avoided.

**Table 2.** Current Consumption in Different Reader Mode

Power supply	Sleep (mA)	Idle (mA)	Scan (mA)	Energy to read one tag (joules)*
SkyeModule M8	<0.1	50	250-650	5.538
SkyeModule M1-Mini	0.06	15	60	1.329
SkyeModule M1	0.06	10	110	2.437

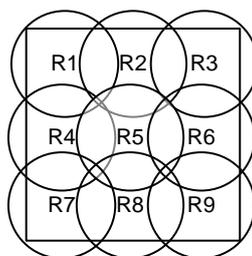
\*Based on data size 96bits, power supply 6 volts, data rate 26kbps

To save the energy, readers need to be slotted and scheduled to be operative. To avoid any missed reading on tag that moves from the reader vicinity without being read, the reader will take turns to be active with the reader resides nearby them. In the case of tag moving from the reader vicinity without being read (because the reader is sleeping) the neighboring reader will cover the readings on the tag. This is because the way we slot the reader to take turns with their neighbors to be active.

### 3. Slotting Algorithm

Slotting reader is one way to achieve energy savings. The benefit of slotting is to avoid collision among the readers. A simple principle to slot the reader is by not having neighboring reader operated at the same time. Neighboring reader can take turns to perform the propagation. The number of slot produced from this algorithm need to be at possible minimum to avoid the risk of miss reading. Otherwise tag might be gone out from the system before it gets to be detected because the length time of each slot taken to complete.

The pre-exquisite to run the slotting algorithm which named as SELECT is we need the list of all readers involved with their adjacent reader(s). We need to sort the reader based on their number of adjacent reader(s). If they have the same number of adjacent reader(s) they will be arranged using alphabet order. Based on Figure 2, R5 is listed at the top because it has the most reader around it which is R1, R2, R3, R4 and R6, R7, R8 and R9. The second to fifth place in Table 3 is tied with each reader has 5 adjacent readers each. We can based the arrangement on ascending orders where the second place is secured by R2 and followed by R2, R4, R6 and R8. For the sixth to ninth position it was R1, R3, R7 and R9 each based on number of adjacent reader and alphabet order. The complete position of readers before the proposed algorithm can be used is shown in Table 3.



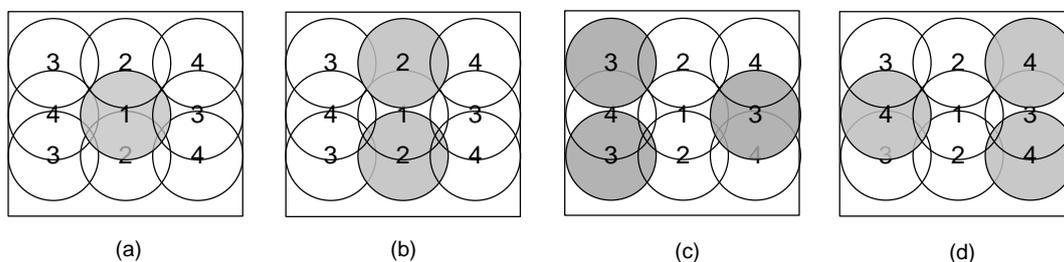
**Figure 2.** Multiple networked RFID readers sitting next to another

When the algorithm starts, it processes the first reader in the list, which is R5. It will assign R5 to slot 1, as R5 has not been slotted yet. Then the algorithm check the adjacent readers to R5, whether any of them have been put in the same slot like R5. It found that no other adjacent reader has been put in the same slot. Then it goes next to the second reader which is R2. According to the algorithm, R2 also will be assigned into slot 1. But when it checks the adjacent reader of R2, it finds that R5 has been put into slot 1. Therefore it change R2 into the next slot, slot 2. For the next reader, R4, is initially assigned to slot1. But the adjacent reader to R4, R5 and R2 has been assigned to slot 1 and 2. Therefore R4 is assigned to slot 3. The algorithm continues until it finishes assign slot to all reader in the list.

**Table 3.** List of Readers Derived From Figure 5

Position	Reader[x]	AdjacentReader[y]
1	R5	R1, R2, R3, R4, R6, R7, R8, R9
2	R2	R1, R3, R4, R5, R6
3	R4	R1, R2, R5, R7, R8
4	R6	R2, R3, R5, R8, R9
5	R8	R4, R5, R6, R7, R9
6	R1	R2, R4, R5
7	R3	R2, R5, R6
8	R7	R4, R5, R8
9	R9	R5, R6, R8

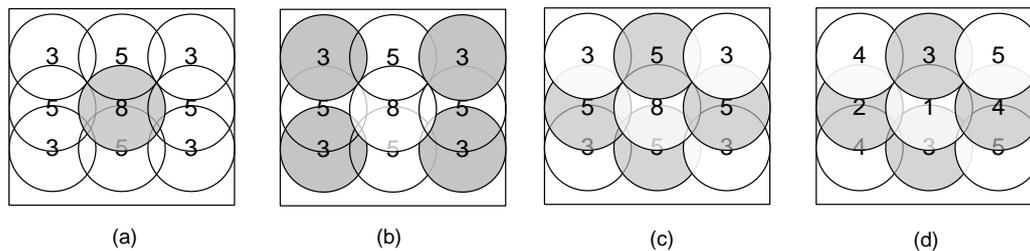
The result for slotting reader in Figure 2 using SELECT is shown in Figure 3. In Figure 3, there are 4 slots for the nine readers. None of the slot contains adjacent readers operating at the same time. At a particular time, only one slot will be operating. The other readers will be put into sleep mode which saves energy.



**Figure 3.** Every reader is assign a slot by SELECT (a) only reader in slot 1 operating (b) 2 reader in slot 2 operating (c) slot 3 operating and (d) slot 4 is operating.

If DCS or Colorwave is used to slot the same networked readers, in the first round of slotting there will be adjacent readers that operate together in the same time which will cause collisions. This is shown in Figure 4. When the collision occurs, the reader need to be assign to new slot, and so does the other adjacent readers. This will delayed the reading process which can increase the chance of missed reading. The number of slot produced also can be higher than what our algorithm produced. The higher number of slot is not good to monitor the tag movement. This is because every slot needs to wait longer time to wait for other slots to finish first.

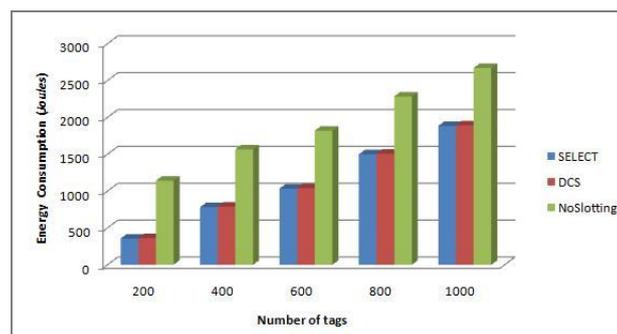
In Figure 4(c) the reader signal in slot 5 will collide with each other causing the all the reader and its adjacent to be assign new slot. This results in whole restructuring of the slot where all the readers were involved as shown in Figure 4(d). The number of slot becomes 5 slots which will take a longer time to finish and consume more energy.



**Figure 4.** Slot assigned by using DCS, two slots are working well as shown in (a) and (b), but slot 5 in (c) experience collision and (d) is the new slot assign after the collision.

#### 4. Performance Analysis

In this section we present result from the experiments we conduct to calculate the amount of energy that can be saved by using our proposed algorithm SELECT. It is compared with the one that is not using any energy savings mechanism (label as no-slotting) and with DCS. For all the experiments we setup 9 readers at fixed location such as shown in Figure 2. The reader then is slotted using the proposed algorithm. Then we randomly placed 200 tags in the interrogation area of these readers. The number of tags is increased by 200 for each sample. We calculated the energy savings for each approach. The energy consumption calculated is the energy to read the tag, the energy in sleep mode and energy to wake up the reader from sleep mode.



**Figure 5.** Comparison of amount of energy consumption using slotting algorithm

In this experiment we want to investigate the amount of energy that can be saved by putting the reader into different slot. The result is shown in Figure 5. Our proposed approach use the lowest energy followed by DCS and no-slotting. Although the amount of differences shown in the graph is small (except for no-slotting) but this comparison is made based on the best possible setting of each approach. This means that the experiment did not take into account the problem of DCS that need to restructure the slot when collision occurs. It also did not take into account the need for no-slotting approach to do reading again due to collision. In the normal practice reading need to be made again when the collision occur. The small difference between SELECT and DCS is because the small difference in the number of slot. DCS have only additional one slot compared to SELECT.

#### 5. Conclusion

In this paper we proposed SELECT to achieve energy savings in RFID. The algorithm principle is to group reader into slot. The purpose of the slotting is to avoid adjacent reader send signal at the same time that causes collision. Based on the case study SELECT produced better slotting result compare to DCS and Colorwave. By having better slotting mechanism collision can be avoided. Energy can be saved because there is no need for signal retransmission to cover the corrupted reading that cause by the collision. The result shows that our algorithm helps to save energy and the amount of energy saved will be greater with the increased of time.

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