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# A Survey of Dynamic Duty Cycle Scheduling Scheme at Media Access Control Layer for Energy Conservation

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## ABSTRACT

From the last few years, wireless sensor network (WSN) s have gained increasing attention from both researcher and actual users. The sensor nodes are generally battery powered. The critical aspects of sensor nodes are to reduce the energy consumption of the nodes, so that the network lifetime can extended to reasonable time. WSN need to provide better performance by reducing the sleep latency, while balancing energy consumption among the sensor nodes. The duty cycle media access control (MAC) scheme have been proposed in WSNs mainly to reduce energy consumption of sensor nodes. There are many scheme developed to reduce the energy consumption to increase the life time of the sensor networks. The scheme Dynamic Duty-cycle and Dynamic schedule assignment (DDDSA) reduced the number of RTS and CTS packet by dynamically updating duty cycle value to achieve energy efficiency .The scheme duty-cycle scheduling based on residual (DSR) energy reduced the sleep latency while balancing energy consumption among sensor nodes. Another scheme is duty-cycle scheduling based on prospective (DSP) increase in residual energy to increase the residual energy of nodes using harvesting and DSR. DSP reduce sensor nodes duty cycle to increase the lifetime of the network through harvesting technique.

## Keywords

Medium Access Control (MAC), Duty cycle, Scheduling, Power consumption, Energy efficiency.

## 1. INTRODUCTION

Wireless sensor networking is an emerging technology that has a wide range of potential applications including environment monitoring, smart spaces, medical systems and robotic exploration. Network consists of large number of distributed nodes that organize themselves into multi-hope wireless routing to perform task. Each sensor consists of one or more sensors, embedded processors and low power radio. The sensing, processing and wireless communication subsystems form the wireless sensor. Each subsystem having the different function such as sensing system sense the data on environment change or according to application requirement, processing system process the acquired data and also stored it in file or

database and wireless communication subsystem can used for data transmission over the network. Sensor nodes are normally battery operated. The power source supplies the energy needed by the device to perform the specified task. It is often difficult to recharge or change batteries for nodes, because nodes may be deployed where human beings unable to reach for example in furnace to sense the temperature etc. The network life time can increase long enough to fulfill the application requirement, by minimizing the energy consumption of the nodes [2].

The energy consumption is greatly affected by the communication between nodes. So, communication protocols at different layers are designed with the energy conservation in the mind. The medium access control (MAC) layer has been proposed in wireless sensor networks mainly to reduce energy consumption of sensor nodes. MAC plays a vital role for successful working of the networks. Also it is responsible for deciding the manner of wireless communication channel and limited resource allocation of communication among nodes. MAC protocols must fulfill some essential factors, such as energy efficiency, effective collision avoidance, scalability and adaptively, minimum latency and efficient throughput of the channel and bandwidth is the secondary in sensor networks. It plays vital role in the performance of wireless sensor network (WSN) s. The major sources of the energy waste are collision, overhearing and control packet overhead. The Collision defined as when a transmitted packet is corrupted, it has to be discarded, and follow on re-transmission increase the energy consumption. Collision increases the latency as well. The Overhearing defined as a node picks up packets that are destined to other nodes. The Control packet overhead defined as RTS and CTS request consume energy too. The major source of energy consumption is idle listening. If nothing is sensed, nodes are in the idle mode for most of the time. Idle listening consumes approximately same power as in transmitting and receiving mode [3].

Most of the sensor node designed to operate for long time. The node will be in idle state for long time and consume more energy. Thus, idle listening is a central factor of energy waste in such cases. The problems occur by idle listening can be solved by the efficient technique called duty cycle. Duty cycle can be defined as the ratio of the node active period to the lifetime of the node. The most effective energy conservation operation is putting the radio trans-receiver sleep mode or low power whenever communication is not required Ideally, radio should off when there is no data to send or receive and should be resume as soon as data or packets becomes available. Depending on networks activity nodes becomes alternate between active and sleep period. This behavior is referred as duty cycling. The duty cycle and node radio *ON* time are directly preoperational to each other, so the significantly saves the energy. The wireless communication system cam performs the transmission and receiving of the data during active sate of the

node. They consume more energy because of radio is *ON* continuously. In sleeping state, they did not perform any activity, so there is minimum energy consumption by keeping radio *OFF* [5].

This paper is organized as follows. Section 2 surveys the duty cycle scheduling. Section 3 describes the contention based MAC. Section 4 discusses the different dynamic duty scheduling scheme for energy harvesting in WSN. Finally, Section 5 concludes this paper.

## 2. DUTY CYCLING

A duty cycling can be achieved through two different approaches such as topology control and power management [3]. The optimal subset of nodes which guarantee connectivity is referred as topology control (TC). Therefore the basic idea behind topology control is to utilize the network redundancy to make longer the network longevity, typically increase the network lifetime with respect to a network with all nodes always on. Here, active nodes do not need to maintain their radio continuously on. They can switch off radio when there is no network activity. Duty cycling operated on active node as power management (PM) through coordinating the sleep periods of neighboring nodes.

Hence, nodes operate on low duty cycle and consume less energy which helps to increase the lifespan of the sensor nodes. Therefore both TC and PM are complementary technique. PM technique can be implemented either at the MAC layer by join together duty cycle scheme at MAC layer protocol or by implementing protocol on the top of the MAC layer.

PM technique classified as sleep/wakeup protocols and MAC protocol with low duty cycle. The sleep/wakeup schemes implemented as independent protocols on the top of the MAC protocol. Independent sleep/wakeup protocol can be further classified as on-demand, scheduled rendezvous and asynchronous schemes.

The basic idea behind on-demand scheme is that a node wakeup when it wants to established the communication over the network to send or receive data. The main drawback of this scheme is how to establish the communication among the sleeping node and the sender.

A scheduled rendezvous approach solve this problem by using the node should wakeup only at the same time as its neighbors. The node wakeup according to a wake schedule and remain active for short duration of the time and goes back to sleep for next rendezvous time .The major advantage of this scheme is that when a node is awake it is guaranteed that its neighbors are awake to send broadcast message to all neighbors. The major advantage of this scheme is that node and its neighbors are wake up at the same time to establish the communication among all the neighbors.



Therefore, nodes try to transmit simultaneously, thus causing a large number of collisions. In this scheme, the size of wakeup and active periods is fixed and does not adapt to variations in the traffic pattern and network topology.

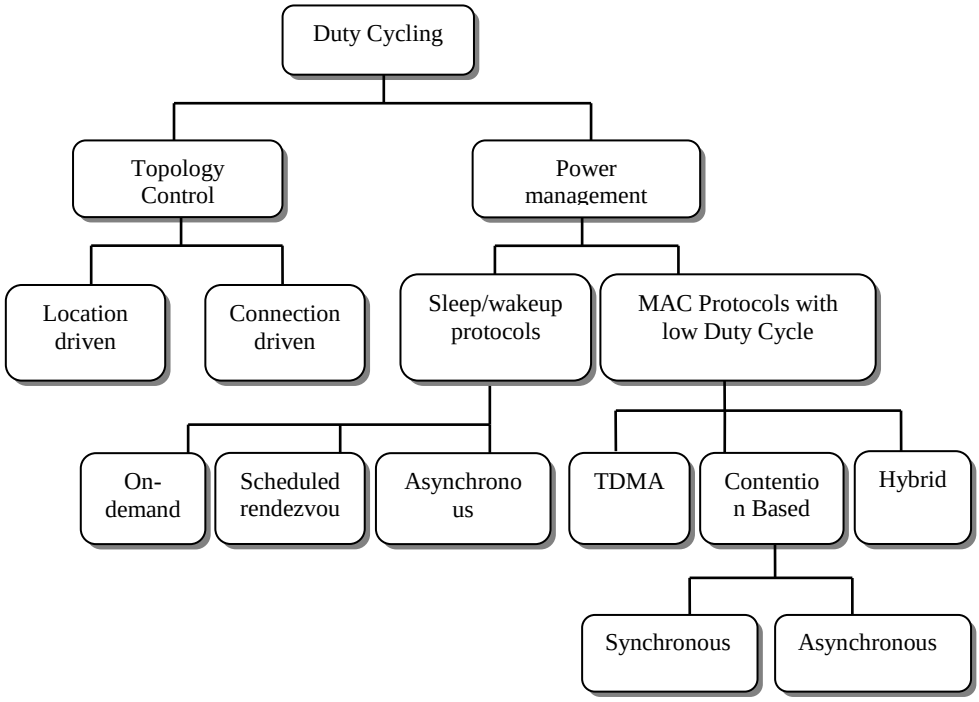


**Figure 1. Taxonomy of approaches to Duty cycling in sensor networks**

Finally an asynchronous sleep/wakeup protocol can be used. With asynchronous protocol node can wakeup when it wants and still be able to communicate with its neighbors. In asynchronous nodes finds the receiver active when it wakes up, is forcing the receiver to listen periodically. The receiver wakes up periodically and listens for a short time to discover any potential asynchronous sender. If it does not detect any activity on channel it returns to sleep, otherwise remains active to send/receive packets. Exploiting cross-layer information seems to be a factor often neglected in the design of asynchronous protocols.

There are several MAC protocols are available, but here power management protocol with low duty cycle are consider. They are classified as TDMA-based, contention-based and hybrid protocols. In TDMA-based MAC protocols time is divided into frames and each frame consists of certain number of time slots. Every node is assign to one or more slots for transmitting or receiving packets to or from other nodes. By assigning slot assignment algorithm and correct sizing of the protocol parameters, it is possible to minimize energy consumption. The TDMA-based MAC protocol

generally used to solve the problem associated with interfacing among the nodes. It has many drawbacks such as limited flexibility and scalability. Because in the real scenario there may be frequent topology changes due to many factors and slot allocation may be problematic, so centralized approach is adopted. Also, it needs the tight synchronization and very sensitive to interference. It has low performance in low traffic conditions.

The contention-based MAC protocols have good performance than TDMA-based protocols because of scalability and robustness. It introduces the lower delay and can easily adapt the traffic conditions. Their energy consumption is more than TDMA because of contention and collision. But duty-cycle mechanism can help to reduce the energy consumption by using low sleep latency.

Contention based protocols achieved duty cycling by tightly integrating channel access functionalities with a sleep/wakeup scheme. This scheme is not an independent of MAC protocol but it is tightly coupled. Contention-based duty cycle MAC can be classified into two categories: synchronous and asynchronous protocols. Synchronous approaches such SMAC [1], T-MAC [8] all nodes listen at the same time for the sender and receiver synchronization. Here the node broadcast their next wake up time to their neighbor and tight time synchronization is required. Neighboring nodes starts exchanging packets only within the common active time. These approaches greatly reduce the idle listening time but synchronization includes extra overheads and complexity and also nodes need to wakeup multiple times if its neighbors are on different scheduled.

Asynchronous protocol such as XMAC [1], RI-MAC [4], RC-MAC [8], AS-MAC [8] are not tightly time synchronous, node can operate on own different duty cycle schedule. Receiver wakeup and if listen the preamble over the channel, it remains in the active state till communication end between the sender and the receiver. They achieve high energy efficiency and remove the synchronization overhead. However they optimize packet delivery ratio (PDA), minimize sleep latency, minimize end to end delay (E2ED) also minimize the energy conservation in the network by using the long preambles.

Finally, hybrid based protocols try to combine the strengths of the both protocols while off setting their weakness. However, these techniques seem to be complex in deployments with high number of nodes. It based on the principle of switching the protocols behavior between TDMA and CSMA depends upon the traffic in the network.

## 3. DUTY-CYCLE SCHEDULING

The energy consumption problem occurred by idle listening and solved by duty cycle scheduling in wireless sensor networks. Tight synchronization



can achieve by defining constant duty cycle over the network. The constant duty cycle defined as static duty cycle scheduling. On the other hand, adaption of duty cycle according to uniform traffic conditions is beneficial in evenly distributed packet traffic which defined as dynamic duty cycle scheduling.

### 3.1 Static Duty Cycle Scheduling (SDCS)

SDCS based on periodic scheduled wake up scheduled for data exchange which consists of the sleep period and an active period. Sensor node can communicate with each other when it in active mode otherwise in sleep mode radio of sensor node is off so they cannot communicate with each other. This approach reduces the idle listening time of the sensor nodes which leads to reduce the energy consumption of the sensor nodes and increases the lifespan of the network. Thus, scheme introduces coordinate sleep scheduled of all nodes to maintain the network level connectivity. The drawback of SDCS is that it increases the sleep latency in multi hope network .So when traffic load is more, it increase number of queue packets due to sleep latency. Many packets dropped due to buffered overflow which increases end to end latency of node. The end to end latency is inversely proportional to throughput. In WSN nodes generally deployed in different location requires different duty cycle to minimize the energy consumption and to increase the lifespan of network. For example, consider the parking system monitoring in malls, they continuously monitors the parked vehicles and data is continuously send to the from leaf node to sink or control system to observed the capacity of the parking place. So nodes deploy near sink needs to transfer the more data than leaf node. Which gives nodes deploy near the sink required different duty cycle according to traffic conditions. Dynamic duty cycle scheduling scheme are proposed to overcome these problems and to increase the energy conservation over the network.

### 3.2 Dynamic Duty Cycle Scheduling (DDCS)

A DDCS used to solve the problems occurred in SDCS. It does not give former knowledge about the global or local timing information and schedules to the nodes in the network. Nodes do not need to remember the scheduled of its neighbors. A DDCS scheme used to dynamically adjusting listening or active period according to traffic load, for the time being, it avoid buffer overflow. It has ability to quickly adapt the sleep/wake up period of each single node to actual operating condition, gives the longer lifespan of the sensor networks. DDCS scheme represent each schedule is independent. Following table describes pros and cons of the SDCS and DDCS.



**Table 1. Comparison of Static and Dynamic Duty-cycle Scheduling**

| Static Duty-cycle Scheduling (SDCS) | Dynamic Duty-cycle Scheduling (DDCS) |
|---|---|
| Required fixed duty cycle for energy conservation. | Required variable duty cycle for energy conservation |
| It cannot adapt to network condition changes such as interference incurred by addition work load at runtime. | Dynamically adjust the sleep interval of each node based on the delay constraint and network condition changes. |
| Save less energy than dynamic duty-cycle scheduling. | Save more energy while meeting end-to-end delay requirement. |

## 4. Dynamic Duty-Cycle scheduling Scheme

Power consumption is a most important issues in WSNs. Dynamic duty cycle scheduling scheme used to reduced the energy consumption by decreasing the number of idle nodes though sleep/wakeup schedule. To used dynamic duty cycle according to traffic condition, Zhang et al. [6] gives a novel duty cycle scheme called Traffic adaptive Distanced-based Duty Cycle Assignment (TDDCA). It assigns dynamic duty cycle value according to traffic and distance which helps to reduce the energy consumption. But in overlapping areas, as the numbers of nodes increase the parameter in overlapping area calculated again and again. It can't give the better performances. To overcome the problem associated TDDCA, Lee and Kin gives Dynamic Phase shift (DPS) approach for reducing the energy consumption [6]. It allows the receiver and sender can exchange the information with each other. It also analysis the uplink and downlink relationships to select the most suitable methods by sender or by receiver. It can avoid collision as well as delay occurs in asynchronous scheme. It used the fixed duty cycle vale for the network.

### 4.1 Dynamic Duty-cycle and dynamic schedule assignments (DDDSA) scheme

To reduce the problem associated with TDDCA and DSP new scheme was developed , DDDSA scheme used to reduce RTS (Request to send)/CTS (clear to send) packets but also updates the duty cycle value according to traffic conditions in network [7]. When there is large number of the sensor node in network, then there is more numbers of idle listening nodes and more duty cycle assignment. To solve these problem DDDCS scheme are used [7]. Firstly, calculate the counter value and broadcast it to other nodes in the network. Also at the same time, a node receives the counter value from the neighboring nodes also. After getting the counter value from the neighboring node it stores it in a queue. Duty cycle increase when



differences between the current received RTS packets are more than original received RTS transmission packets. This value used as priority to other node. Duty cycle values is increase if collision occurs frequently occur in the overlapping area. Depending on the priority it decides which node should serve first and reduce the traffic load. There are some more scheme are developed to reduce the energy consumption of the node one of them is DSR which helps to reduce the energy consumption of the sensor nodes.

### 4.2 Duty-cycle scheduling based on residual energy (DSR) scheme

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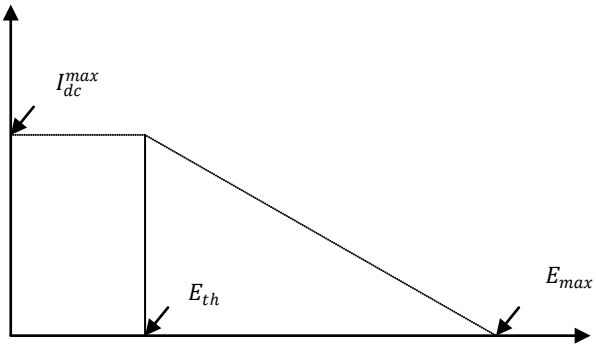


**Figure 2. Decision graph of DSP scheme**

Duty-cycle scheduling based on residual energy is used to reduce the sleep latency, while balancing energy consumption among sensor nodes [1]. Sleep latency defined as a sensor node which has packet to transmit is usually required to wait for long period before transmitting the packet. Minimum sleep latency reduces energy utilization of sensor nodes, so it helps to increase the lifetime of sensor the networks. DSR allows each sensor node to determine its duty cycle considering only its residual energy every time node wakes up. Thus, duty cycle is inversely to residual energy. Calculate the duty cycle of each node and residual energy of node. Let node number denoted by 'i' , ' $I_{dc}$ ' denotes duty cycle of node number i and $E_r$ denotes the residual energy of the node .Generally, $I_{dc}^{i}\ \alpha\ \frac{1}{E_r^i}$Where $I_{dc}^{i}$ is duty cycle of $i^{th}$ node and $E_r^i$ is residual energy of $i^{th}$ node. In DSR, maximum duty cycle is denoted by $I_{dc}^{max}$ , which is application specific parameter. If $E_r$ less than $E_{th}$ then $I_{dc}^{i}$ set to $I_{dc}^{max}$ .If $E_r^i$ greater than $E_{th}$ then calculate $I_{dc}^{i} = I_{dc}^{max} - (I_{dc}^{max} * \left(\frac{E_r^i - E_{th}}{E_{max} - E_{th}}\right))$ where, $E_{max}$ represent the maximum$E_r$. Outcomes of the mechanism are in case where $E_r^i$ becomes equal to $E_{max}$ , the node I awakes all the time. As residual energy of the node $(E_r^i)$ decreases, duty cycle of the node $(I_{dc}^{i})$ increases.



### 4.3 Duty-cycle Scheduling based on Prospective increase in residual energy (DSP) scheme

In DSP, the residual energy of nodes can increase over time depending on their harvesting opportunity, regardless of the progress of the energy consumption [1]. If node adopt this prospective to increase whenever wake, they allow to used duty cycle $(I_{dc}^{i})$ smaller than the current residual energy.

Let consider the one scenario, where all nodes are equipped with a solar panel to harvest the energy and one node ' *A*' the covered by shade at all time and has no chance of harvesting, while at the same time another node '*B*' has continuous chance of harvesting opportunity.

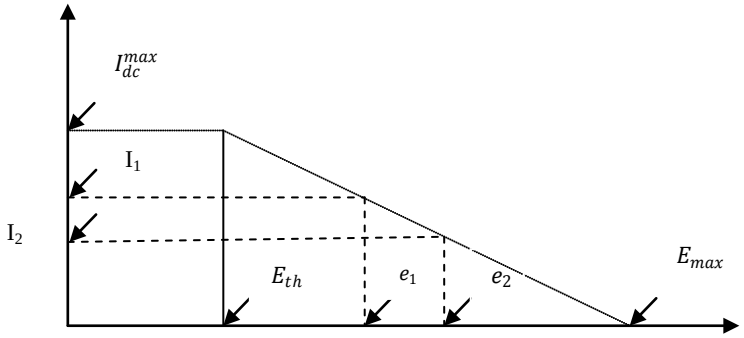


**Figure 3. Decision graph of DSP scheme [1]**

At start both node '*A*' and '*B*' have same residual energy such as $(E_r^A)\ and\ (E_r^B)$ , in DSR duty cycle of both node is $(I_{dc}^{i})$. In DSP, node '*B*' can have $(I_{dc}^{B})$ less than node duty cycle of the node '*A*' $(I_{dc}^{A})$ because of the harvesting opportunity available to node '*B*'. The residual energy of the node '*B*' increases over time due to harvesting opportunity in spite of the energy consumption. When node wakes up then calculates its increase in residual energy with time($R_{surplus}^{i}$) as,$R_{surplus}^{i} = (R_{eh}^{i} - R_{ec}^{i})$Where, $R_{eh}^{i}$is energy harvesting rate and $R_{ec}^{i}$ is energy consumption rate. DSP allows node i to reduce $(I_{dc}^{i})$ of the node more aggressively than DSR. Here, $E_r^i$ increase continuously only if $R_{eh}^{i}$ greater than $R_{ec}^{i}$ and $E_r^i$ greater than $E_{th}$ otherwise it's working same as DSR. Suppose consider node i work at time 'c' its residual energy$E_{r(c)}^{i}$. So $R_{surplus}^{i}$ during last time interval T ahead at time 'c+T' and residual energy becomes $E_{r(c+T)}^{i} = E_{r(c)}^{i} + (R_{surplus}^{i} * \mathrm{T})$ .

Therefore, to select smallest duty cycle which minimize the sleep latency without losing current amount of residual energy even in '*T* 'second. In figure 3 let $e_1$ and $e_2$ denotes $E_{r(c)}^{i}$ and $E_{r(c+T)}^{i}$ and $I_{dc}^{i}$ sets to $I_2$ not $I_1$.Energy harvesting opportunities depends on the spatial temporal variations in energy availability so to predict '*T*' value becomes difficult. If



'*T*' value is not proper it gives the energy duplication. To minimize the energy depletion DSP required to be recomputed $I_{dc}^{i}$ every time when node wakes up. The '*T*' value should large enough to allow node 'i' to reduce $I_{dc}^{i}$ aggressively also it should small as $R_{surplus}^{i}$ decrease over time.

## 5. CONCLUSIONS

There are many scheme developed to reduce the energy consumption to increase the life time of the sensor networks. The scheme Dynamic Duty-cycle and Dynamic schedule assignment (DDDSA) reduced the number of RTS and CTS packet by dynamically updating duty cycle value to achieve energy efficiency. Both DSP and DSR have better performance.DSP gives the higher packet delivery ratio and lower end to end delay than static duty cycle scheduling scheme. It proves DSP scheme has better performance than DDDSA and DSR regardless to the performance metrics because of the aggressive behavior. In future, we expect more efficient scheme for energy conservation by modifying the DSP scheme.

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## REFERENCES

[1] Hongseok Yoo, Moonjoo Shim and Dongkyun Kim, *Dynamic Duty-Cycle Scheduling Schemes for Energy Harvesting Wireless Sensor Networks* IEEE communication letter, Vol 16, No. 2, February 2012, page no.202-204.

[2] Jennifer Yick, Biswanath Mukherjee, Dipak Ghosal, *Wireless sensor network survey*, Elsevier , Computer Networks 52 (2008), page no. 2292-2330.

[3] Giuseppe Anastasi, Macro Conti, Mario Di Francesco, Andrea Passarella, *Energy conservation in wireless sensor networks: A survey*, Elsevier, Ad-Hoc Networks 7 (2009), page no. 537-568.

[4] Yanjun Sun, Omar Gurewitz, David B. Johnson, *RI-MAC: A Receiver-initiated Asynchronous Duty Cycle MAC Protocol for Dynamic Traffic Loads in Wireless Sensor Networks*, ACM Sensys, 2008.

[5] Yan-Xiao Li, Hao-Shan Shi, Shui-Ping Zhang, *An Energy-Efficient MAC protocol for wireless sensor network*, 3rd International Conference on Advanced Computer Theory and Engineering(ICACTE), 2010.

[6] Giuseppee Anastasi, Macro Conti, Mario Di Franceso, *Extending the Lifetime of Wireless sensor Networks Through Adaptive Sleep*, IEEE Transactions on industrial informatics, VOL5,NO3, August 2009.



[7] Hsin Hung cho, Jian-Ming chang *An energy efficient dynamic duty cycle and dynamic schedule assignment scheme for WSNs*, 2011 IEEE Asia –specific Service Computing Conference.

[8] Pei Huang, Li Xiao, Soroor Soltani, Matt W. Mutka and Ning Xi *The Evolution of MAC Protocols in Wireless Sensor Networks: A Survey*, IEEE Communications survey and tutorials, VOL 15, No 1, First Quarter 2013.