A Review on Broadcasting Protocols for Duty-Cycled Wireless Sensor Networks

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***Abstract*— Developments in Wireless Sensor Network (WSN) technology have brought about a substantial number of applications. A basic issue in WSNs is most sensors are outfitted with limited-powered batteries because of which the lifetime of those nodes are short and limited. One of the solutions for this problem is Duty Cycle (DC) scheme which can save the node's energy by proposing active/sleep periods. However, because of this DC scheme network has to face more additional problems such as- transmission delay, low delivery rate, increasing number of transmission in case of broadcasting command to other nodes of the network etc. Many researches have been done in this field for solving those issues and many more are still going on. In this paper, we have focused on the current progresses in Broadcasting protocols for DC-WSNs.**

Keywords- Wireless Sensor Network, Duty-Cycle, Broadcasting Protocol, Energy-Efficiency, Transmission Time, Latency, Network Lifetime

1. INTRODUCTION

Wireless sensor networks (WSN) comprise of spatially distributed sensor nodes, which can monitor the surrounding by collecting, processing and transmitting the information to sink node. Every sensor node comprises of a constrained power source, radio through which sensor node can connect with other nodes under its connecting territory. Be that as it may, a lot of power is devoured by node elements regardless of whether they are in use or not.

Duty cycle is counted as one of the great solutions for saving the node's energy as well as prolonging lifetime in WSN [1]. In a duty cycle the sensor nodes are periodically sleep and awake for a specific number of time slots. Asynchronous DC makes the network enter into a time-varying topology. Because of the implementation of DC in WSNs many issues are raised in order to gain the objective optimizations for different types of transmission mechanisms [2].

One of the most significant communication techniques in WSNs is broadcasting algorithm. It is an essential mechanism to re-program sensor nodes in a network or to look for specific data from all nodes. As broadcasting is a communication service where every node in the network needs to collaborate, the energy consumption for this mechanism is significant. Hence, a broadcast algorithm should be modeled for minimizing the energy consumption, such as re-transmissions, collision and transmission latency.

The main goal of broadcasting protocol is to deliver the data packet to each and every sensor node of the network. In DC-WSNs, synchronized node can easily transmit their broadcast message since they are already aware of their neighboring nodes' sleep/awake time and can wake up at the same time to transmit. But that is static and also there is synchronization overhead. On the other hand, in the asynchronous system nodes wake up independently therefore, nodes need to wait until their destination node wake up which leads to transmission latency and consume more energy. Another problem is when a parent node has different child with different sleep/awake time then it needs to re-transmit the same message for those different active time slots.

To solve these issues related to broadcast algorithm, many solutions have been proposed in the literature. However, none of them can solved the issues entirely. There are still some lose ends remaining. In this paper we have discussed about some recent developments of broadcasting algorithms for DC-based WSNs [3]-[8]. We have studied through those modified algorithms and pointed out which optimization goals are achieved and which are skipped.

The remainder of the paper is organized as follows: the motivation of the research and the core mechanism of broadcasting algorithm have presented in Section 2, different broadcasting protocols for DC-WSNs proposed in recent times are briefly described in Section 3, in Section 4 a comparison table is presented based on the survey analysis of those protocols and Section 5 has concluded the work.

2. BROADCASTING PROTOCOL

One of the most significant technologies which strengthen WSNs' is Software Defined Network (SDN) technology [9]. SDN technology is used for replacing the

design of hardware by software. Using of SDN makes it easier for updating the functionality of the application or network specification through necessary code distribution to all the nodes of the networks at the same time in order to speed up the update process. This technology is faster in this area and attracted extensive attention already from researchers and industries as well [9].
Among various research issues in this field one important issue is how to broadcast program code commands to all the nodes of the network quickly whereas avoiding extra energy consumption. But because of using DC in WSNs the broadcast mechanism facing latency problem and ended up using extra energy in order to transmit several times. Hence, many researches have been done on Minimum Transmission Broadcasting (MTB) problem in order to minimize the number of broadcast transmissions [10]. The purpose of reducing the number of transmission is to save energy, reducing delay and thus prolonging network lifetime.

In this study we have observed the 1-to-n transmission method which is a sender node sends data to n nodes. Since the wireless networks have the ability to broadcast which can send data packets to multiple receiver in one single transmission hence has the ability to reduce energy consumption by cutting off the number of transmissions. Figure-1 is showing the diagram of basic broadcasting mechanism in DC-WSN.

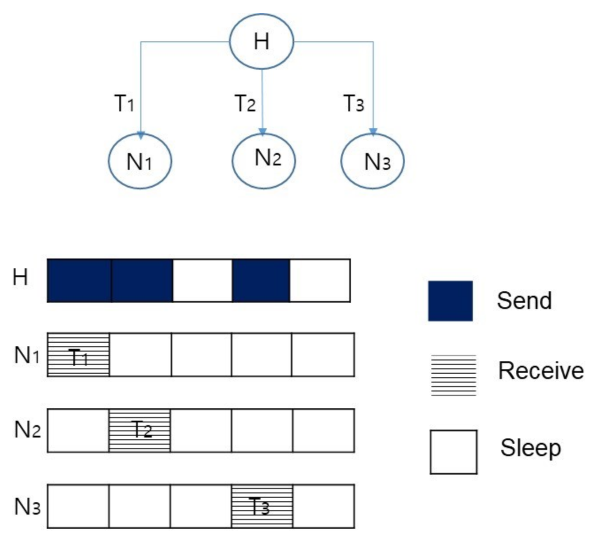

Figure 1: Conventional Broadcasting mechanism in DC-WSN.

3. Broadcasting Protocols for DC-WSN

In the recent years many researches have been conducted regarding the objective of minimizing the transmission time and also some researches have done where they have considered the link reliability issue in order to have a successful transmission for avoiding retransmission. They have focused on the objectives such as-minimizing the number of transmission, lower down the delay, minimizing the energy consumption and also maximizing the network lifetime. Table-I is presenting the achieved goals of the mentioned algorithms and the brief analysis summary is given bellow:

i. Adaption Broadcast Radius-based Code Dissemination (ABRCD)

In this work Yu *et al.* [3] focused on MTB problem which goal is to reduce broadcast redundancy and where the broadcast radius is assumed to be fixed in the whole network. They have proposed an ABRCD scheme in order to reduce delay and improve energy efficiency in duty cycle-based WSNs. There they set a larger broadcasting radius in those areas where comparatively more energy is stored than other areas. By their proposed scheme they have achieved 3 objectives. First, because of the bigger broadcasting range the information can successfully transmitted to the targeted source with fewer hops while cut out the number of broadcasts as well as latency. Second, broadcasting information can reach out to more number of nodes in one transmission which will again reduce the number of total transmissions. And finally, even though larger radius in this scheme consumes more energy for some transmitting nodes, this radius extension is only done on those specific areas with an energy surplus, moreover, energy consumption in the hot-spots can be reduced on the other hand because of some nodes sending data directly to destination nodes without forwarding by nodes in the original hot-spot, hence energy consumption can be balanced and network lifetime can be extended.

ii. If Fail Add Slot / Before Try Add Slot/ Add Average Place Slot (IFAS/BTAS/AAPS)

In this work Wei *et al.* [4] aimed to minimize the delay and the number of transmission at the same time for achieving longer lifetime while broadcasting data in high loss ratio and low duty cycle WSNs. They have proposed multiple awake time slots where the child nodes of the same parent can share the same awake time slot matched with their siblings in order to get the transmission at the same time in case there is a transmission failure. They have also observed the extra energy usage for the case where the base station is in longer distance and thus tried to improve the strategy for better performance. If in case parent node fails to transmit to its one of the child nodes then that child node will add an extra wake-up slot in the cycle, matched with other sibling nodes wake-up time-slot so that when parent node transmit again for another child then the previous child node which had failed to receive the data can now get the chance to receive that data successfully. It will reduce the waiting time and will decrease the energy consumption at the same time. They have proposed three mechanism for adding the extra slots IFAS, BTAS and AAPS, which they have proved experimentally efficient by their simulations.

iii. Broadcast Sharable Slot-Slotted Sense Multiple Access Broadcasting (BSS-SSMAb)

In this work Yoo *et al.* [5] has observed the characteristics of Reliable Slotted Broadcast Protocol (RSBP) protocol and find out the problems it faced from low reliability in harsh environments and low responsiveness to the changes in network topology. They have proposed to synchronize the awake time slots of all the child nodes according to their parent node to allow broadcasting at the same time for the parent node. They have proposed to allocate one specific BSS to each tree level hence made a BSS schedule topology-independent. As a result, nodes in the same level can rebroadcast a packet to the nodes which are one level higher than them within the BSS which will allow redundancy. This characteristic will ensure the link reliability property of the network. However, the proposed work has got the probability of facing collision in case of having two child node transmitting at the same time. Therefore, this scheme is not applicable for densely located network services.

iv. Q-Learning based MAC (QL-MAC)

In this study Claudio et al. [6] has aimed to focus on prolonging the lifetime of the network on the territory of high-density communications in WSNs. Here they have used reinforcement learning technique which is an important method in AI in order to yield an energy efficient MAC protocol which will help to prolong the network lifetime. They have made the use of Q-learning which iteratively work on the MAC variables using trial-and-error method in order to converge to a low energy state. Their proposed QL-MAC protocol reached out 2 optimal objectives. One is solving the minimization issue without the help of predetermining system model and another one is facilitating a self-adaptive protocol for topological and other external changes. The disadvantage of the proposed work is that it got the high possibility of losing packets.

v. Adaptive Intelligent Hybrid Medium Access Control (AI-HMAC)

In this paper the Ahmad et al. [7] considered two important protocol design-based constraint problems, energy and latency and proposes a joint TDMA and CSMA-based traffic Adaptive Intelligent Hybrid Medium Access Control protocol (AI-HMAC) for low-power duty cycle WSNs. The objective of AI-HMAC is to modify the link scheduling and using contention windows mechanism of IH-MAC and smooth the coordination among them by avoiding delay and to efficiently achieve energy consumption. Their proposed mechanism has two benefits. One is being able to operate under wide range of data traffic and choosing send/receive mechanism technique according to packet rate and loss with extending energy minimization techniques and bringing down energy consumption. Another is to regulating initial contention window according flowing traffic asking rate between nodes in order to achieve high channel utilization under high traffic load without any energy compromising and to minimize certain delay probability that may cause with data collision. However, in their work the authors did not show any experiments on improving network lifetime comparing with other protocols for efficiency evaluation. Therefore, the proposed scheme is not applicable for real-world applications.

vi. Trickle Timer-SDN-WISE

In this work Hieu et al. [8] has focused on how to reduce the number of transmission in order to reduce energy consumption for Software-Defined WSNs based on SDN-WISE. In SDN-WISE, routing polices are defined by a controller which is a software that can be anywhere in the network. They proposed a new mechanism for SDN-WISE, called Trickle Timer, which allows sensor nodes in a wireless network to exchange few packets per hour when network's state remains stable. Their provided simulation results show that the implementation of the Trickle timer in SDN-WISE provides better performance in terms of energy consumption and transmission, reception duty cycle. However, the limitation of the proposed scheme is that it only focused on link reliability and energy consumption, whereas avoiding other important objective goals.

4. Comparison Analysis

Motivated by the literature works, in this section we have tried to summarize our survey on latest broadcasting algorithm based protocols for DC-WSNs. We have provided a comparison table, Table-I in order to get an idea about the studied algorithms how much they have achieved the ideal goals at a glance.

5. Conclusion

In this work, we have studied newly established six DC-WSN based broadcasting protocols in order to get an easy review on the current status of the research in this area. However, we have done a thorough analytical survey on the data provided in the literature works. As a future work, we will try to simulate those algorithms and can compare which one can achieve better performance with achieving the best objective parameters such as duty cycle, latency, energy consumption, network lifetime, and throughput.

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Table I. Surveyed Broadcasting Protocols for DC-WSNs.

DC Broadcast Algorithms	Objective Optimization				Remarks
	Minimization of Broadcast Transmissions	**Minimization of Delay**	**Energy Efficiency**	**Maximization of Network Lifetime**	
ABRCD[3]	Yes	Yes	Yes	Yes	Cannot show good result for increasing time slots
IFAS/BTAS/AAPS[4]	Yes	Yes	Yes	--	Evaluated for a specific network model.
BSS-SSMAb[5]	No	Yes	Yes	--	Possibility of collision occurrence due to simultaneous broadcasting.
QL-MAC[6]	--	--	Yes	Yes	Higher probability of packet loss
AI-HMAC[7]	--	Yes	Yes	Yes	Did not compare the Network lifetime with state-of-art protocols
Trickle Timer-SDN-WISE[8]	--	--	Yes	--	It only focuses on link reliability and energy consumption whereas skipping other important objectives

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